Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

MARCH 1959

RE-ENTRY AND HYPERSONICS

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EDITORIAL

RE-ENTRY AND HYPERSONICS

NEWS

DEPARTMENTS

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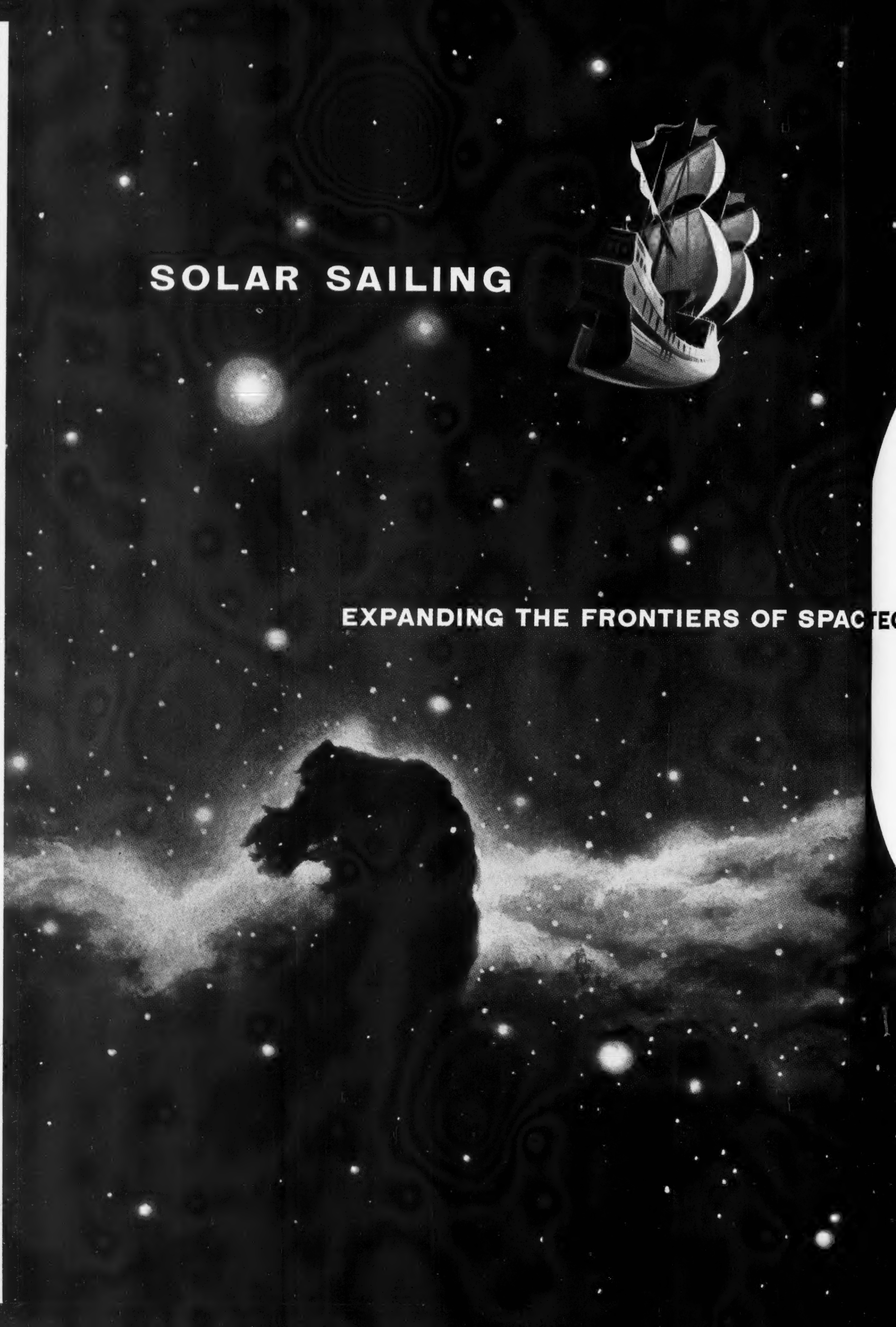

Astro notes

ASTRONAUTICS

• By way of a telephone interview to a correspondent in South Africa, Professor A. A. Blagonravov of the U.S.S.R. Academy of Sciences, frequent spokesman on the Soviet space program, revealed that the Soviet Union had chosen its first space pilot, one Ivan Igorsky, a bachelor 30 years old and weighing 180 lb. Blagonravov also asserted that Russia planned to launch rockets to Venus, Mars, and possibly the moon by September of this year. "Our idea," he said, "is to establish a New Russia on the planets Mars and Venus. We . . . are now preparing to land a rocket on Venus in June. . . ."

• Generally overlooked in the excitement over the Soviet Lunik was its demonstration that the Russians now possess a rocket system of sufficient power and accuracy to send a large payload on an interplanetary mission. The U.S. is perhaps two years away from a similar capability. Should it elect to enter a race for Venus, this country would have to settle for tiny payloads boosted by Thor-Able and Juno rocket assemblies. These systems are limited in accuracy, and their small size would pose insuperable power, orientation, and communication problems.

• All available evidence indicates Russians sought to score a direct hit on the moon with Lunik. Successful use of radiation and magnetic field detectors would require a much closer pass than the 4660-mile miss achieved by Lunik. In addition, the short battery life, large number of telemetry channels, and presence of Soviet insignia devices indicate a direct hit was sought. Based on Soviet press statements and sketchy U.S. tracking data, it appears that Lunik arrived at the vicinity of the moon about 2 hr early, passing "ahead" or to the east of it. This could have been caused by a slight excess in burnout velocity.

MAN IN SPACE

• NASA selected McDonnell Aircraft as the source for the design, development, and construction of the Project Mercury space capsule (see page 43). Collins Radio was promptly selected by McDonnell to develop complete instrumentation, including radio voice communication, radio command of capsule, capsule-to-ground telemetry, and rescue radio beacon system. Minneapolis-Honeywell will design and build the system of gyroscopes, reaction jets, and associated electronics for capsule attitude control. M-H is also working on Dyna-Soar and a two-man space-cabin simulator for the AF School of Aviation Medicine.

• The Project Mercury space capsule will get its first workout at NASA's Wallops Island test station aboard a rocket assembly called "Little Joe." North American is providing this assembly, which consists of Sergeant and Recruit motors clustered in a side-by-side arrangement. Four Little Joe shots are planned with dummy payloads and two with the full-scale McDonnell capsule. The firings, which will have neither human nor animal passengers, will test the stability of the capsule configuration as well as recovery techniques. They will probably not exceed an altitude of 50 miles.

• A carefully selected group of 12 volunteers to pilot the capsule will commence a rigorous training program as capsule testing gets under way. The small group will be the cream of the finest AF and Navy test pilots. The astronauts will undergo acceleration tests in the Navy's Johnsonville, Pa., centrifuge, weightless tests in aircraft, as well as in special equipment devised at WADC, extended balloon flights, and, finally, ballistic flights of increasing range. The latter will be conducted from Cape Canaveral, using the Redstone. Probable date for the first manned orbiting attempt—sometime in 1962.

• ARS President John P. Stapp announced AF is considering a balloon-lofted manned vehicle boosted to near orbital speed by solid rockets as a means to train space pilots and to solve problems in the develoment of rocket-powered airliners, to conduct further research in the upper atmosphere, and to study military reconnaissance. The vehicle would maneuver with the aid of a throttled rocket engine.

• Convair, as expected, received the Project Centaur contract to develop and build an Atlas upper stage for satellite and space-probe experiments. Pratt & Whitney will develop the propulsion system. With this upper stage, Atlas could put as much as 5 tons into a low orbit. NASA will take over responsibility for the project July 1.

SPACE RESEARCH

• Military scientists are still studying the large volume of upper atmosphere data secured last summer during the two high-altitude nuclear bursts over Johnson Island in the Pacific. Though military findings are shrouded in secrecy, evidence from unclassified sources indicates that the shots had a profound effect on the upper atmosphere. Most immediate was a fadeout of commercial radio frequencies (5 to 25 mc), lasting up to a day in the Pacific. A New Zealand scientist reported the appearance of an artificial aurora. James Van Allen's radiation instruments in Explorer IV, launched only a few days earlier, reported a sharp upsurge in radiation intensity following the bursts. At least some of the upper atmosphere effects persisted for many months. IGY scientists observed the appearance of a new line in the twilight spectrum—lithium—which persisted through the fall and into the winter of 1958.

• Some hint of the global scope of the Johnson Island blasts may be found in the recent AF disclosure of a radiation measurement program conducted with the five-stage solid-propellent "rocket trains" developed originally by NASA for re-entry tests. A total of 16 rockets, fired from Western Hemisphere sites (Ramey AFB, P.R.; Cape Canaveral; and Wallops Island), carried 60-lb packages of radiation instruments to an average altitude of 550 miles. Although AF would not connect the shots with the Johnson Island tests, it is known that they occurred about the same time. Presumably, they measured such things as particle injection, transport, lifetime, and identity.

• Principal objective of the Johnson Island tests was to determine design principles for anti-missile warheads. A major question was whether anti-missiles should seek to destroy targets by thermal shock or neutron irradiation. (A dense flux of neu-

trons could neutralize a ballistic missile warhead by inducing a "pre-initiation" in the fissionable trigger.) It is believed the tests showed the latter procedure to be highly promising. This would be in line with calculations showing that a given nuclear warhead can produce a lethal radiation envelope (500 to 5000 roentgen) eight to 17 times larger in space than at sea level.

• The tests provided considerable data to facilitate the design of space weapon systems, but in so doing they may add support to efforts in the UN aimed at limiting space to peacetime uses. This is because the tests show man can readily duplicate the effects of solar flares in the upper atmosphere, and that these effects will persist for many months by virtue of the trapping effects of the Earth's magnetic field, just as the Van Allen radiation belt is confined. This means the manned space operations of any nation will remain in permanent jeopardy unless a space agreement is reached, and it also casts grave doubt on the ability of any manned fighting machine to survive beyond the atmosphere for any length of time in the face of a thoughtful enemy.

SATELLITES

• Eyebrows were raised over the announcement that ARPA will launch several "navigation" satellites by mid-1959. With little visible requirement for such satellite in evidence, Capital observers were wondering whether the new breed would carry certain undisclosed reconnaissance experiments along with radio beacons. It appeared to many that the government is resorting to still another cover-up to conceal supporting research for the Sentry reconnaissance satellite program. First of the so-called navigation satellites will be a 150-lb battery-powered package which will stay aloft about three months. It will presumably be launched by a Thor-Hustler rocket from Vandenberg AFB as part of the Discoverer program.

• ARPA's 1959 program will also include several communications satellites in the spring and summer, and a meteorological satellite next fall or early winter. The meteorological program will be turned over to NASA July 1. (Meantime, NASA will conduct its own weather satellite program. A Vanguard shot with an Army Signal Corps cloud cover experiment was planned for February.

• The 1.2 million-lb-thrust clustered rocket motor (Juno V) which the Army is developing for ARPA should receive its first ground tests late this year. ARPA has ordered four booster assemblies for test flights, possibly beginning in 1960. Consisting of eight 150,000-lb-thrust Rocketdyne engines with separate propellant tanks, the clustered engine should be capable of boosting 20 tons of payload into orbit.

• Study of the motion of the Vanguard satellite has shown that Mother Earth is slightly pear-shaped, with the more narrow half above the equator and the sag below. NASA's Theoretical Div., directed by Robert Jastrow, rates this as the second most important finding from satellite studies to date, just behind the discovery of the Van Allen radiation fields. They interpret the deformation to mean that the crustal layers of the Earth have more strength and less elasticity than thought.

SPACE LAW

• The ARS Space Law and Sociology Committee, headed by Andrew G. Haley, is organizing a special conference in New York, to be held March 20. Called the "ARS Conference on a Down-to-Earth Agenda on Legal and Sociological Problems of Space for the Consideration of the UN Ad Hoc Committee on the Peaceful Uses of Outer Space," the meeting will be held at the Carnegie Endowment for International Peace Building, across from the United Nations Building in Manhattan.

MISSILES

• Before the Senate Preparedness Subcommittee, Defense Secretary Neil H. McElroy asserted that the U.S. will maintain a diversified arsenal of long- and short-range missiles and, for the next year or so, bombers rather than shift to heavy emphasis on ICBM's. He testified that Snark will be discontinued and that Polaris will go into service with less than the advertised 1500-mile range. He declined to say if Polaris range would drop to 1000 miles or less, as has been rumored.

• The fiscal 1960 military budget will complete the Thor and Jupiter intermediate-range missile programs unless there is some last minute interest in the weapons by this nation's overseas allies. Present plans provide for five squadrons of Thors and three of Jupiters (15 missiles per squadron). Four Thor squadrons are to be deployed in England and two Jupiter squadrons in Italy. It is hoped France will accept the remaining two squadrons, but there is a possible alternative of locating them in Greece and Turkey. Should additional foreign interest materialize, military assistance funds would be used to finance further production.

• AF plans a total of 300 intercontinental ballistic missiles in place by mid-1963. These would include nine Atlas squadrons and eleven Titan squadrons (10 missiles each), plus two squadrons of Minuteman ICBM's (50 each). AF budget for fiscal 1960 continues the accelerated Atlas program and provides for a 50 per cent increase in funds for Titan and a 40 per cent increase for Minuteman.

• Fairchild's long-range decoy missile, Goose, was a casualty of changing strategic concepts, according to McElroy. As the day of the ballistic missile approaches, he explained, it becomes increasingly urgent to order retaliatory bombers on their way at the first sign of an alert. The bombers can always be recalled, but the missiles can't. Consequently it is conceivable that the bombers might reach their targets before the decoys which are designed to confuse the defense and pave the way for the bombers. The latter, he stated, will still be equipped with airborne decoys (McDonnell's Green Quail).

• Extent of the military shift from manned aircraft to missiles received further illumination in the new Pentagon budget. The Administration requested funds for only 1610 new aircraft for all three military services, 150 fewer than last year. No new interceptors will be procured for the Air Force in fiscal 1960. The only manned aircraft weapon systems currently under development for the Air Force are the B-70 chemical bomber and the F-108 long-range interceptor—both Mach 3 aircraft being developed by North American.

• Lockheed and Westinghouse, under technical direction of NOTS, are conducting underwater launching tests of dummy Polaris missiles at San Clemente Island, off the Southern California coast. Firings from the ship's motion simulator at Cape Canaveral should be under way now, with preparations for sea firings from the test-ship Observation Island in the offing. Polaris went some 800 miles in a Canaveral ground-launching Jan. 10, in a test termed partially successful by the Pentagon.

• The third time proved a charm for Titan, which took off success-


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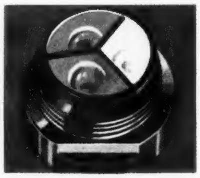

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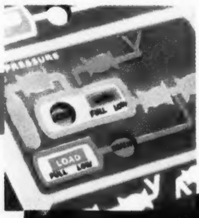

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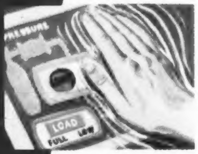

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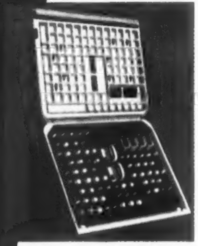

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fully from Canaveral Feb. 7 in a test of launching equipment, telemetry, safety provisions, and missile structure. Its second-stage contained water as ballast, the nose cone was a dummy. The missile failed to get off the pad in a firing the week before, and failed twice in static firings since the first free-flight attempt in December.

• Demonstration firings of the Lobber supply missile developed by Convair began in January at Redstone Arsenal. The missile carries a payload of 50–200 lb about 6 miles, and can be converted to a weapon carrying a napalm or high-explosive warhead.

NASA

• NASA appointed chairmen for the 13 Research Advisory Committees formed to provide technical counsel for national space and aeronautical programs under the agency's management. Committee chairmen are: W. R. Sears, Cornell Univ., Fluid Mechanics; R. R. Heppe, Lockheed, Aircraft Aerodynamics; H. Guyford Stever, MIT, Missile and Spacecraft Aerodynamics; Louis N. Ridenour, Lockheed Missile Systems Div., Control, Guidance, and Navigation; James A. Reid, Astrodyne, Chemical Energy Processes; W. H. Jordan, Oak Ridge National Lab., Nuclear Energy Processes; Gordon Banerian, Aerojet, Mechanical Powerplant Systems; E. Z. Gray, Boeing, Structural Loads; E. E. Sechler, Cal Tech, Structural Design; Martin Goland, Southwest Research Institute, Structural Dynamics; R. H. Thielemann, Stanford Research Institute, Materials; and William Littlewood, American Airlines, Aircraft Operating Problems.

• NASA will take over the Chincoteague (Va.) Naval Air Station, which the Navy planned to close, and run it in conjunction with its Wallops Island facilities. This will save NASA an estimated $2.5 million in expanding its programs at Wallops.

SPACE COMMITTEES

• After spearheading the House Space Committee since its inception last year, and seeing the Committee's succinct and forceful final report on "A Space Program for America," issued early in the year, House Majority Leader John W. McCormack (D-Mass.) retired as chairman in favor of Overton Brooks (D-La.), who was previously second-ranking member of the House Armed Services Committee.

• Rand Corp. "Space Handbook" prepared for the House space committee has become "must" reading around Washington. An examination of the present and future state of the art in lay terms, it provides a factual, well-documented, easily understandable look at astronautical technology and applications, as well as astronautical activities in other countries. The report will be published in book form shortly.

• Appearing before the House Space Committee, Rear Adm. John T. Hayward, Navy R&D Chief, advocated one national space program with one agency responsible for it. Citing the weakness of the schism between NASA and ARPA, he suggested that NASA be broadened to operate like the AEC, with a division for applying research to military developments.

R&D

• NASA has awarded the first contracts on a family of high-performance solid rocket engines to be used to put miniaturized payloads into orbit.

• The variable-thrust liquid-propellant rocket engine disclosed by NOTS will soon be flight-tested. This is the first news to come from NOTS on a rocket motor of possible use in space projects, e.g., the balloon-launched pilot-training rocket proposed by Col. Stapp, or interplanetary space craft for return to Earth. NOTS has worked on high-performance liquid-propellant systems for over 10 years.

• ITT Astrionics Lab at Ft. Wayne, Ind., will study space-vehicle guidance from mid-course flight to landing under an ARDC contract.

• A SNAP generator capable of delivering as much as 100 w will power the Sentry satellites video scanner. This is one of a series of generators under development by the AEC and Martin during the past five years.

• ABL and the Naval Propellant Plant are developing a double-base solid motor for possible use in Polaris. Indian Head will modify and add to its facilities to make pilot production of the motor possible.

• In the AF Minuteman program, Tapco Div. of Thompson Ramo Wooldridge and Pratt & Whitney Div. are doing studies of movable nozzles for thrust-vector control. The Standard Oil of Indiana R&D Lab is developing solid-propellant gas generators for the Minuteman auxiliary power supply system.

• The new Esso Research and Engineering group will research both petroleum-based and other high-energy solid propellants under a one-year, $1.264 million contract from Army Ordnance.

• Kiwi-A, the AEC's research reactor for an atomic rocket, is now expected to receive its first low-level run early in spring.

• Los Alamos Scientific Labs and General Atomic will share ideas and information in studying space-ship propulsion by a series of small nuclear explosions.

• Studies by S. M. Bogdonoff and I. E. Vas of Princeton's James Forrestal Research Lab show that spike-tips on nose cones can reduce both heating rate and drag, allowing re-entry at a considerably higher Mach number for a body with given heat capacity. They also suggest that a variable-length spike might control drag coefficient in atmospheric flight better than a variable-geometry skirt, and point out the possible usefulness of a spike in lowering heat transfer and pressures over the after-surfaces of a hypersonic aircraft.

MATERIALS

• Bureau of Mines metallurgists at Albany, Ore., produced the first molybdenum casting of any consequence—a cylinder $4^1/_2$ in. in diam and 8 in. long. Molybdenum is potentially of great importance for space craft because it maintains a low-friction surface in a vacuum and has good strength at high temperatures. The group also has produced the first pliant form of yttrium, which melts at 2825 F and has a fairly low nuclear cross section, making it a candidate construction material for high-temperature, solid-element nuclear reactors, i.e., the kind expected for the first nuclear-powered rocket. Yttrium has thus far been ranked well below such metals as molybdenum and niobium as possible structural materials, in part due to its brittleness.

FACILITIES

• The Navy's Pt. Arguello missile facility, including a fire-control building and two launching pads, will be built by Wells-Benz Inc. of San Diego under a $4.6 million contract. These facilities will be part of the Pacific Missile Range.

• Collins Radio Co., subcontractor to MacDonnell Aircraft for the Project Mercury communications sys-

tem, will develop a high-density microwave communication system for the Pacific Missile Range under a $2 million Navy contract.

• Boeing will add to its present seven wind tunnels an arc-discharge hotshot tunnel with 40 in. section for testing models in the range Mach 10–27. This tunnel will be the largest privately owned one in the country.

INDUSTRY

• Stauffer-Aerojet-General will produce high-energy boron-based fuels under a $2 million AF prime contract which calls for design, construction, and operation of a pilot plant at Aerojet's Sacramento facilities. Stauffer-Aerojet expects their process to greatly reduce the production cost of boron fuels. Aerojet is also engaged in a $30 million expansion of its solid-propellant facilities at Sacramento to handle increased work on the Polaris, Minuteman, and Dyna-Soar programs.

• Lockheed, Chrysler, and Martin stepped closer to the space age with new names and organizations Lockheed changed the name of its Missiles Systems Div. to the Lockheed Missiles and Space Div., which includes among its projects ARPA's Discoverer satellite, the Sentry reconnaissance satellite, and Polaris. Chrysler has formed an Advanced Projects Organization within its Defense Products Group to work on major missile and space projects; this new group, for instance, is working with ABMA on the Juno V clustered-engine booster. Martin-Baltimore split into two new divisions—Manned Vehicles and Missile Electronics—in preparation for the upgrading of certain missile and space projects.

• United Aircraft and Stanford Research Institute have formed United Research Corp. to do research on rocket propellants.

OCCASIONS

• The AF School of Aviation Medicine commemorated the 10th anniversary of the founding of its Dept. of Space Medicine last month. This pioneering group was established under the direction of Maj. Gen. Harry G. Armstrong and was first headed by Hubertus Strughold, now the School's adviser for research.

EDUCATION

• UCLA is offering a course in ballistic and space vehicle systems this semester. Coordinated by Howard S. Seifert, ARS vice-president, the course got under way last month and will run through June 8.

• MIT's new Dept. of Aeronautics and Astronautics, headed by Charles S. Draper, is giving a Space Environment Symposium consisting of 12 afternoon lectures by guests from other institutions, for example, Harold C. Urey of the Univ. of California, Herbert Friedman of NRL, Fred Whipple of the Smithsonian Astrophysical Lab, and Richard Herzog of Geophysics Corp. of America. H. Guyford Stever, chairman for the series, announced that the lectures, which began Feb. 16 and end May 14, are open to the public free of charge.

EUROPE

• Cooperation seems to be the byword in European missile, rocket, and space flight activities these days. France, Italy, and Germany are working on a joint program for production of the U.S. Hawk ground-to-air missile, selected for NATO countries. Meanwhile, Germany and Italy are studying a cooperative sounding-rocket program.

• Italy expects deliveries to begin this Spring of 30 Jupiter IRBM's, 100 Nike-Ajaxes, and a number of U.S. air-to-air and Hawk ground-to-air missiles. France is delivering 1000 Nord SS-10 anti-tank missiles, while the U.S. Navy will deliver either Terrier or Talos missiles as armament for three Italian cruisers and a new destroyer. Contraves Italiana is also designing a stabilized platform for Contraves-56 missiles to be used on Italian warships.

• Italian Air Force has organized a missile school at Padova, a step toward formation of missile squadrons. Instructors were selected from a large group of Italian airmen who received special instruction in the U. S. Nike launching pads are expected to be ready in the not-too-distant future.

• The wire-guided Cobra anti-tank missile developed by the German firm of Bolkow K.G. in Otterbrun (Munich) is another weapon under consideration for NATO use. The 17.6-lb missile reaches a speed of 260 fps, has a 5000-ft range. It has already been bought for experimental purposes by the Swiss Army.

• The Danish Army is expected to order the French SS-11 anti-tank missile. Recent tests involving firings from an Alouette Helicopter have been termed "very satisfactory." Denmark will also soon receive Sidewinders.

• The recent Swedish order for Bristol Bloodhounds is said to have amounted to $4–5 million. Deliveries are expected to start in about 18 months.

JAPAN

• The Japanese Defense Agency has allocated almost 25 per cent of its 1959 defense budget to R&D work on missiles. Some 400 million yen will be spent for research on domestically produced air-to-air missiles, the U.S. air-to-air Sidewinder, and Swiss ground-to-air Oerlikon and U.S. Nike missiles.

• A new cosmic ray detector of the neon hodograph type, said to be one of only five in the world, has gone into operation at Tokyo Univ.

• The Japan Council of Science has set up a permanent liaison committee of cosmic and space researchers to coordinate Japanese activities in these fields.

• Tokyo Astronomical Observatory estimated that Lunik was launched from a site approximately 130 miles northwest of the Caspian Sea—approximately the same point from which the Sputniks had been launched, according to Japanese calculations.

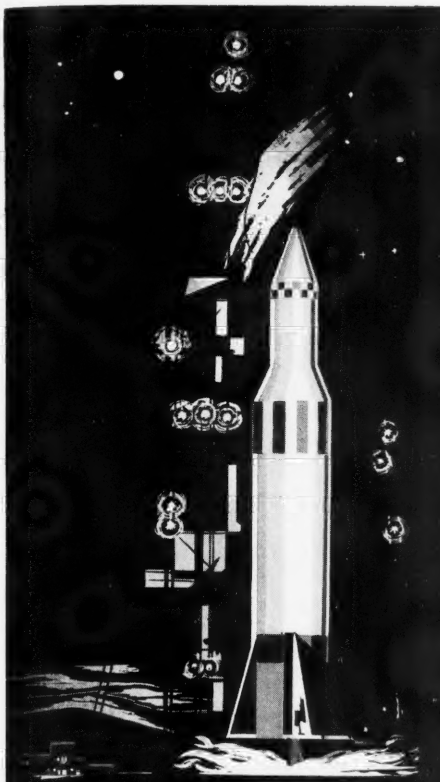
• A Kappa rocket zoomed to a new altitude record of about 30 miles in the last shot carried out as part of Japan's IGY upper-atmosphere rocket research program.

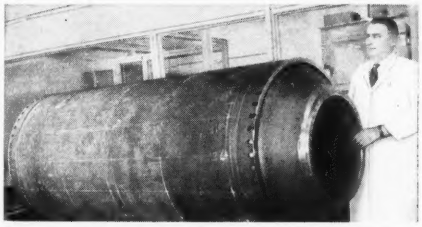
GREAT BRITAIN

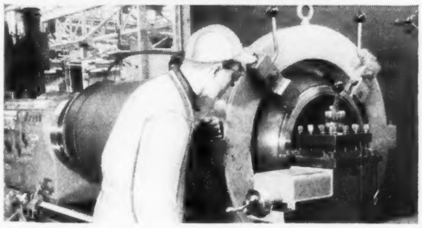
• Britain's Royal Society, taking up the ball tossed to them by Minister of Supply Aubrey Jones, recommended launching scientific satellites for basic research. Great Britain, however, has had only one announced successful high-altitude firing of its Black Knight ballistic rocket and none of the IRBM Blue Streak, either of which might serve to launch minimum-weight satellites. Any British satellite thus appears at least a year away. So far the Ministry of Supply shows no sign of backing a British man-in-space program.

• The British are believed to be using hydrogen peroxide in the Black Knight, now under test at the Woomera Range. The rocket performed satisfactorily in its only announced flight test at the range, the nose cone impacting at almost the exact point predicted and being recovered successfully.

• Polaris may join Britain's first line of missile offense, rather than its own liquid-propellant IRBM Blue Streak, now under development.







F-108, NUCLEAR TURBOJET, AND RAMJET PROJECTS OFFER CHALLENGING OPPORTUNITIES TO PROFESSIONAL ENGINEERS AND SCIENTISTS

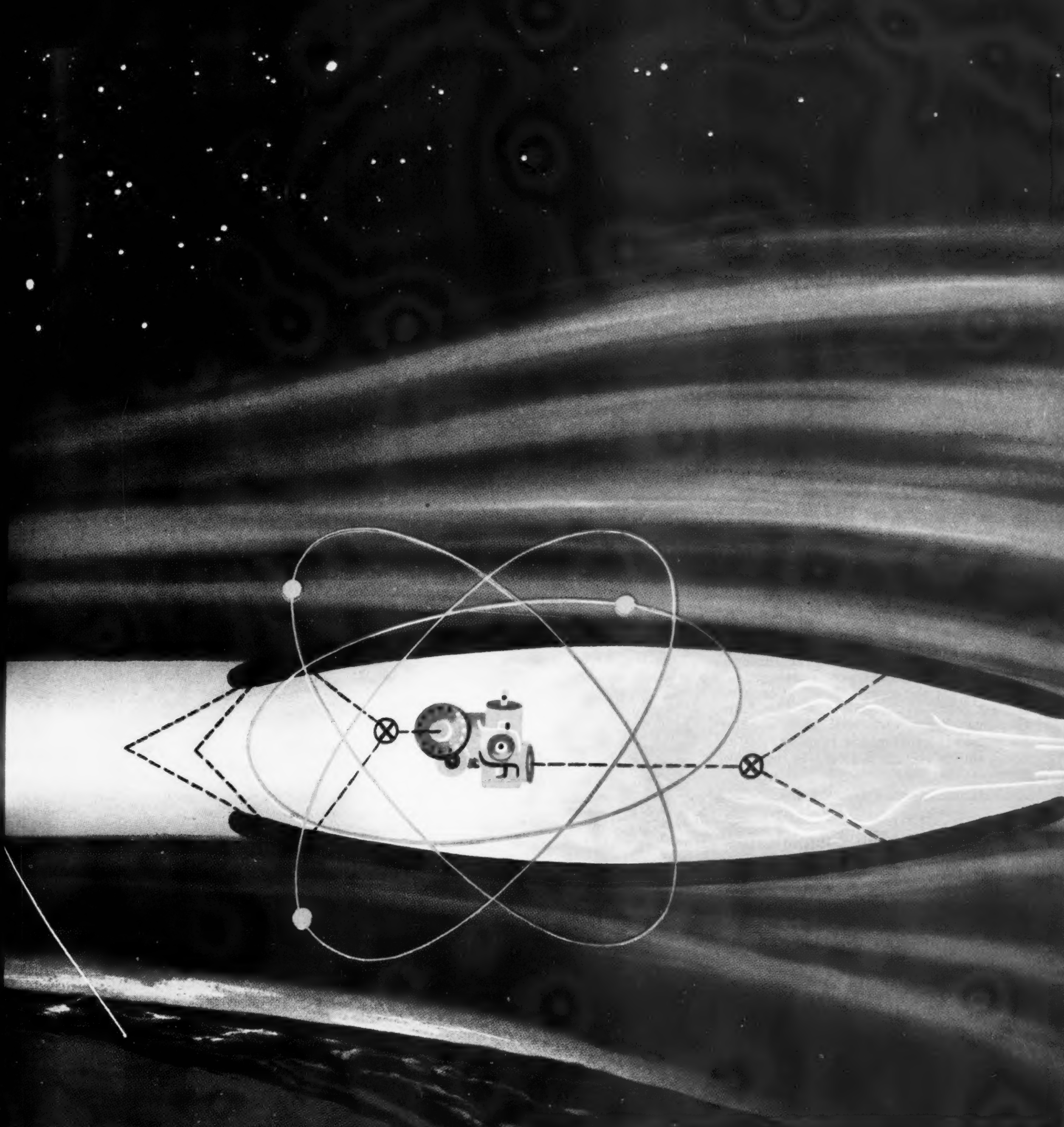
Advanced projects for air and space operations now underway in the Controls and Accessories Division at Marquardt Aircraft offer engineers and scientists challenging opportunities in a variety of technical areas. Here, where we are dealing with development problems on high-performance systems with stringent design and reliability requirements, professional engineers will find real challenge and opportunity for accomplishment.

Project personnel are currently working in such areas as the engine control system for the G-E nuclear turbojet; inlet control systems for the McDonnell F-4H, North American F-108 and the North American Hound Dog missile; the fuel control system for the supersonic Bomarc's ramjet engine; auxiliary power systems, pumps, and actuators; and are developing a unique and advanced space power unit.

C & A Division activities range in scope from preliminary design through final production.

Professional engineers and scientists capable of making contributions in these and related areas are invited to investigate the employment opportunities at Marquardt. You will find a combination of significant, active projects and a lively interest in new ideas, creating an environment for professional growth. May I suggest you write Mr. Floyd Hargiss, Professional Personnel Department, 16542 Saticoy Street, Van Nuys, California?

Roy E. Marquardt, *President*



The mail bag

A Definitive Source

Dear Sir:

Your handling of the information concerning the performance of the Hercules Powder Co. third-stage engine for the lunar probe is appreciated. The clarifying statements made in the January 1959 issue of ASTRONAUTICS will serve to strengthen the reputation of your publication as a definitive source of information.

BARNET R. ADELMAN
Director, Vehicle Engineering Laboratory
Space Technology Laboratories
Los Angeles, Calif.

Wrong Country

Dear Sir:

Your interesting report on the International Astronautical Congress at Amsterdam in the October 1958, ASTRONAUTICS, contains a slight mistake. On page 41, referring to the re-election of our dear friend Andrew G. Haley . . . it states that his re-election was promoted through a suggestion of the Argentine delegation.

This is not the case. The election proceeded from a suggestion by Dr. Luis Gonzaga Belivacqua, delegate of the Sociedade Interplanetária Brasiliera (Brazilian Interplanetary Society) to the Congress . . .

I take this opportunity to congratulate you on the splendid quality of ASTRONAUTICS.

PROF. FLÁVIO A. PEREIRA
President of the International Scientific Council, S.I.B.
São Paolo, Brazil

Praise for Kenmore

Dear Sirs:

Maybe its because of the favorable song he has to sing, but I really like Robert H. Kenmore's column. I would be glad to subscribe to your magazine even if Mr. Kenmore were the only writer. His analysis and way of describing the situations are the best in his field.

R. A. COOLEY
Executive Vice-President
Propellex Chemical Division
Chromalloy Corp.

Translated from The American?

Dear Sirs:

In the event that this has not already been drawn to your attention by Dr. Richard Porter himself or his associates, I would like to point out an evident case of a Soviet translation of an American paper being misconstrued to be an original Soviet contribution.

This occurs in the November 1958 issue of ASTRONAUTICS in the article entitled "Behind the Red Satellites" by F. J. Krieger, on page 104. A "Soviet" satellite recovery project described by V. Petrov is a direct copy (translation) of the article: "Next Satellite Problem: Data Descent" in Aviation Week, May 14, 1956, in which Dr. Porter's plan to utilize a stainless steel balloon to recover data from an Earth satellite is discussed.

Incidentally, the terminal velocity calculated in this article is erroneously low (30 fps), being based on the supersonic drag coefficient of a sphere, ($C_D = 1.0$), rather than a low-speed, relatively high Reynolds number $C_D = 0.2$ or so.

R. E. KNIGHT
Astronautical Section
Weapons Systems Department
Goodyear Aircraft Corp.

Want Cover Reprints

Dear Sirs:

I agree with reader LeShane (Mail Bag, November 1958) that reproductions of some of your excellent covers would indeed make attractive decorations for the office or study. If you would care to put my name on a waiting list until such time as you deem it feasible to make extra copies available, it would be much appreciated. I am more than willing to purchase them at cost.

I found the March 1958 ("Atlas at 80,000 ft"), June 1958 ("X plus 15"), and July 1958 (X-15 aircraft) covers most dramatic and most representative.

STEWART E. BOWEN JR.
Monrovia, Calif.

Gentlemen:

In regards to Albert A. LeShane's letter commending your magazine's covers, I agree wholeheartedly with him. Some of the covers have been outstandingly artistic—especially the symbolic paintings on the October 1957, and September 1958, issues. In addition, I also enjoyed the beautiful rocket takeoff pictures on the March, June, and July issues of 1958.

If enlarged copies of these covers are available for purchase, I would certainly like to put my order in.

ROBERT F. ZAPPA

Dear Sir:

In answer to your comment in the November "Mail Bag" about back issue covers—I, for one, would be interested in some of these. One cover picture I would particularly like to obtain is the March '58 picture "Atlas at 80,000 ft." I think this is one of the most outstanding pictures I have seen.

Hope they can be made available.

GEORGE F. EAST
Whittier, Calif.

Poetry Department

Dear Sir:

The following is for your edification—or mine—or someone's!

COLUMBUS GO HOME

Columbus sailed the ocean blue,
In fourteen hundred ninety-two.
Proving, we heard, the earth not flat,
Showing it rounder than a derby hat.

Astronautics scanned the sky so fine,
In nineteen hundred fifty-nine.
Proved the Ancients right, what fun!
Showed earth's flatness, 298 to 1.*

LESTER COLE

* January, 1959, p 48.

Outer-Space Ion Density

Dear Sirs,

In the "Capital Wire" column in the October issue, I notice a statement relative to my proposal for neutralizing the recently discovered radiation belt which may confuse the reader.

The statement reads: "Singer believes there are only a relatively small number of particles in the earth's geomagnetic trap. His figures indicate a total charged particle population of only 10 to the 16th. . ."

It should be made clear that I am referring here to high-energy particles only, and that these have no relation to outer-space ion density, which is, of course, greater by a factor of perhaps a million. However, these ions are of extremely low energy and are in no way dangerous. . .

S. Fred Singer
Department of Physics
Univ. of Maryland
College Park Md.


US AIR FORCE


ENGINEERS AND SCIENTISTS
FOR COMPLETE
SPACE AND WEAPONS SYSTEMS
Rarely does a corporation of United Aircraft's stature make available such key positions. Ordinarily these openings would be filled from within, but as the other divisions (Pratt & Whitney, Sikorsky, Hamilton Standard, Norden) cannot spare additional valuable staff men, these openings must be filled from the outside. You will work beyond ordinary boundaries on
MISSILE AND SPACE PROJECTS
Unusual, infrequently offered, high level positions for:
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AERONAUTICAL ENGINEERS
MECHANICAL ENGINEERS
PHYSICISTS
Please reply to Mr. John North, Engineering Dept.
MISSILES & SPACE SYSTEMS
A Division of
UNITED AIRCRAFT CORP.
437 Main Street, East Hartford, Conn.

For the record

The month's news in review

Jan. 1—Russians say they will be able to send a rocket around the moon this year.

Jan. 2—U.S.S.R. launches $1^1/_2$-ton cosmic rocket, Mechta, reportedly heading sunward to become mankind's first artificial planet.

Jan. 4—Russians report Mechta has passed the moon.

—NASA Chief T. Keith Glennan says first task of the agency will be to develop long-range U.S. space program.

—Grumman Aircraft, Republic Aviation, and Fairchild Engine and Airplane Corp. announce they will collaborate on missile and space projects "whenever advisable."

Jan. 5—Russians report Mechta's radios have gone dead 374,000 miles from Earth.

Jan. 6—Soviet Academician A. A. Blagonravov says Mechta was Russia's first attempt to launch an interplanetary rocket.

—AT&T President Frederick R. Kappel says his company can develop anti-ICBM missile.

Jan. 7—Russians claim Mechta has swung into orbit around the sun.

—Navy scraps Project RAT (rocket-launched torpedo).

Jan. 8—AF discloses it is working on new techniques to recover nose cones of Discoverer satellites, "including recovery by aircraft."

—House space committee report predicts U.S.S.R. will be first to send a man into space.

—FCC asks views on proposal to set aside radio frequencies for space communication.

Jan. 10—House space committee urges bold U.S. space program to surpass Soviet Union.

—Anthropomorphic dummy in space suit passes 1200 mph sled test at Holloman AFB.

Jan. 12—NASA chooses McDonnell Aircraft to develop and build Project Mercury man-in-space capsule, at a cost expected to exceed $15,000,000.

—Soviet Union releases following data on Mechta: Multi-stage rocket was launched vertically; automatic control system switched off last stage engine and separated instrument package weighing 769.5 lb; last stage housed devices for assuring normal flight, a sphere containing scientific and radio instruments, two transmitters with antennas, a cosmic ray counter, and sodium vapor spray.

Jan. 13—Radio of Atlas satellite is silent.

—Woman subject spends almost seven straight days in a darkened isolation chamber at AF Aero Medical Lab.

Jan. 14—AF awards Convair contract for an Atlas upper stage that could achieve escape velocity.

—President Eisenhower concedes Soviet leadership in certain phases of missilery.

Jan. 15—AF Atlas ICBM fails after 200-mile trip.

—First Bomarc launched at Eglin AFB, Fla., marking beginning of move to Eglin from Cape Canaveral of firings of shorter-range missiles.

Jan. 16—AEC displays compact 5-lb atomic generator, tagged Snap III, possible power source for satellite instrument packages.

—Russian's report Mechta perihelion is 90,968,560 miles, closest it will come to sun.

Jan. 18—Navy unveils NOTS-developed rocket engine and simple control system for manned interplanetary flights and soft lunar landings.

—U.S.-Soviet agreement on exchange of scientists nears final okay.

Jan. 19—President's budget message indicates that production of Jupiter and Thor missiles will end when authorized quotas are met.

—Navy Polaris travels only 60 miles of 800-mile goal in test shot.

—AEC and AF create Life Science Working Group for Aircraft Nuclear Propulsion.

Jan. 21—AF gets extra $13 million for advanced weapons program, including missiles.

—First tactical Jupiter launched by Army hits its target in 1700-mile test.

Jan. 23—AF Thor-Able falls far short of 4400-mile range in test.

—SS American Mariner, seagoing missile measurement laboratory, sails on secret mission aimed at developing ballistic missile defense.

Jan. 27—U.S.S.R. suggests international cooperation in planning of cosmic flights.

—AF sends Atlas 4000 miles in test.

Jan. 28—NASA announces selection of 110 candidates for test pilot of first man-in-space capsule.

—Gen. Nathan F. Twining, chairman of Joint Chiefs of Staffs, says neither Russia nor U.S. has ICBM's in combat positions.

Jan. 29—NASA scientists report Earth is pear-like, according to data from Vanguard satellite fired last March 17.

—Defense Sec'y. Neil H. McElroy tells Senate Preparedness subcommittee U.S. will not race Soviet in ICBM production.

Jan. 30—Wernher von Braun, ABMA, and Homer J. Stewart, NASA, tell Senate Preparedness subcommittee Soviet ICBM could pinpoint a U.S. city, and that U.S. lags behind Russia by about 20 months in rocket and space technology.

Jan. 31—AEC semiannual report to Congress reveals agency is considering relaxing strict secrecy surrounding atomic weapons for last 14 years.

Streaking down to earth from space, X-15's skin of Inconel "X" alloy will glow with the dull cherry red of a tossed rivet. X-15, the first manned space-probe ship, is built by North American Aviation, Inc.

How X-15 survives red-hot re-entry

When the first manned space-probe ship, X-15, streaks in from space to re-enter the earth's atmosphere, air friction heats its nose and leading edges to a dull, glowing red in seconds.

Temperatures as high as 1000°F build up. Temperatures that could easily weaken the skin of the X-15. Temperatures that *melt* aluminum. *Deform* carbon steels. *Destroy* most other materials.

How could designers make it possible for X-15 and her pilot to return safely?

The answer was found in the high-temperature properties of Inconel "X"*, an age-hardenable nickel chromium alloy. Inconel "X" alloy offers the high-temperature strength X-15 needs to make its red-hot comeback into the earth's atmosphere.

Does this versatile alloy suggest a way you can get some problem facing you off the ground? Inconel "X" alloy provides good spring properties as high as 1000°F. Its relatively low coefficient of expansion makes it useful for parts which must move within tight clearances at high temperatures. And its oxidation and corrosion resistance at high temperatures are outstanding.

In short, Inconel "X" alloy or one of the other versatile Inco Nickel Alloys may offer you a way to cut costs or improve some product so it can re-enter the business picture. Our new booklet, "High Temperatures Spur Use of Nickel-Base Alloys" contains additional data to get you started. A postcard will bring you a copy.

*Trademark of The International Nickel Company, Inc.

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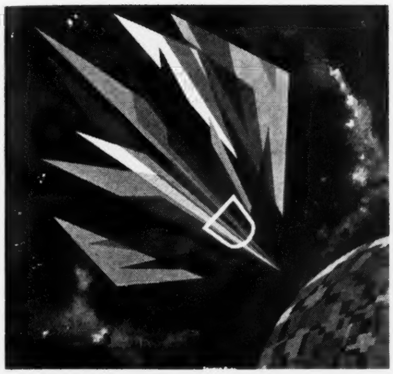
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL ALLOYS



COVER: *"Re-Entry," by artist Edward Ryan, whose cover for the September 1958 issue has won many plaudits.*

Astronautics

MARCH 1959

The President's Letter

On Jan. 8, your President helped activate the ARS Fenn College Student Chapter at a joint ARS-ASME meeting in Cleveland. The Cleveland-Akron Section is ably led by Section President Paul M. Ordin.

The following evening, the Southern Ohio Section sponsored a joint dinner meeting with the local chapter of the American Radiological Society, addressed by your President. Interest in ARS is thriving in Cincinnati.

On Jan. 13, the Northern California Section held a dinner meeting at San Jose where your President spoke. Outgoing President Ed Quarterman has done a wonderful job of building up this section.

The Holloman Section held a board of directors meeting at the home of its President, Knox Millsaps, on Jan. 19, to discuss topics of interest with your President. On a local advertising budget, Editor Jim Hanrahan publishes a monthly bulletin of purely local content for free distribution. It is a model of free enterprise, representing many hours of time donated by business manager Frank Smith and the volunteer staff.

On Jan. 20, through weather fit to stampede the Eskimos, your President reached Kansas City, Mo., via jet T-33 piloted by the dauntless AF Capt. Joe Kittinger of Manhigh balloon fame, just in time to acknowledge an introduction and dedicate the new Kansas City Section of our growing Society. Good luck to President Alan Pittaway and his valiant colleagues.

On Jan. 25, arrived in New York for the ARS National Board and Executive Committee meetings. Executive Secretary Jim Harford and his staff reported a 56 per cent membership increase during 1958, and a transition in one year from red to black on the books. The publications staff is deserving of an ovation for outstanding success. Also, Immediate Past-President George P. Sutton is deserving of a Distinguished Service Award for his leadership in gaining new professional and technical stature for the Society during the past year.

—Col. John P. Stapp (USAF-MC)
President, American Rocket Society

The nature of re-entry

Not simply a problem of aerodynamics and thermal-protection systems, re-entry in the broad sense depends sensitively on guidance, random dispersion, and total effectiveness of the vehicle system

By George E. Solomon

SPACE TECHNOLOGY LABORATORIES, INC., LOS ANGELES, CALIF.

George E. Solomon is director of the STL Astrosciences Lab. He was educated at the Univ. of Washington and CalTech, where he received a Ph.D. in aeronautics and physics in 1953, and was a fellow in the fields of transonic flow and boundary layer research. For the past several years, Dr. Solomon has worked on ballistic missile re-entry and missile technology problems.

SUCCESSFUL re-entry represents one of the greatest state of the art advancements in the field of aeronautics in recent years. The usual problems of boundary layer heating and boundary layer transition are greatly complicated by the conditions of re-entry, which, for example, produce very large temperature variations across a boundary layer and, because of the high temperatures involved, cause the air to dissociate.

In addition, problems new to engineering aeronautics have been introduced by the extremely high velocities of re-entry—radiation from high-temperature "air" as a significant source of heat; flow-field, i.e., the velocity and pressure distributions, at Mach numbers greater than 20; the complicated interaction between a high-energy gas stream and a surface material which interacts both dynamically and chemically with the gas boundary layer; and deceleration loads up to 80 g.

In the past few years, our technical knowledge in these areas has greatly increased and has been applied successfully to solving practical re-entry problems. The interaction between the re-entry problem and other subsystems of a missile system are not discussed in the other articles in this issue. Since these interactions and "trade-offs" have a very important bearing on research and development trends in re-entry, both past and future, some discussion of the system problems will help to explain the "nature of re-entry."

Before discussing the interaction of re-entry body and weapon system design, a few comments relating to the nose-cone design problem are appropriate.

At relatively short ranges, the problem of re-entering a ballistic missile payload has been solved by employing common engineering materials and techniques. However, at ranges of the order of 1500 miles or greater, the problem takes on an entirely new complexion. For example, the energy content of the 5000 n.mi. re-entry body is approximately 10,000 Btu/lb, and, since this is more than enough energy to completely vaporize any known practical material, some other energy absorption means must be employed if a usable payload is to result.

In a now famous NACA report of 1953, H. J. Allen and A. J. Eggers proposed a solution to this dilemma. In brief, they showed that a high-drag configuration would cause most of the kinetic energy to be dissipated in nonisentropic air compression taking place

through the shock wave system about a blunt body. For a very blunt body, over 99 per cent of the energy could be dissipated in this manner, leaving less than 1 per cent to be accommodated by the re-entry body mass. Several techniques and materials are available which will effectively absorb more than 100 Btu/lb and thus allow good net payloads for ICBM ranges.

Numerous techniques can be considered for absorbing or rejecting re-entry heating. Need for reliability and simplicity in weapons will generally mitigate against mechanically complicated systems, such as liquid-metal cooling or transpiration systems. Aerodynamic heating rates with high-drag bodies are extreme, i.e., they may be several times larger than the heating rate at the sonic throat of a rocket engine. Hence, radiative cooling is unattractive, since insulation requirements would be excessive. Two general approaches remain attractive, namely, the solid heat sink and the ablation, or mass transfer, techniques.

The solid heat sink approach utilizes the thermal capacity of a metal skin to absorb the convective and radiative heat transfer from the "air" about the re-entry body. Since the heating period is rather short (of the order of a few tens of seconds), the conductivity and related thermal properties of the heat sink material are important in determining the heat absorbing capability of the heat sink.

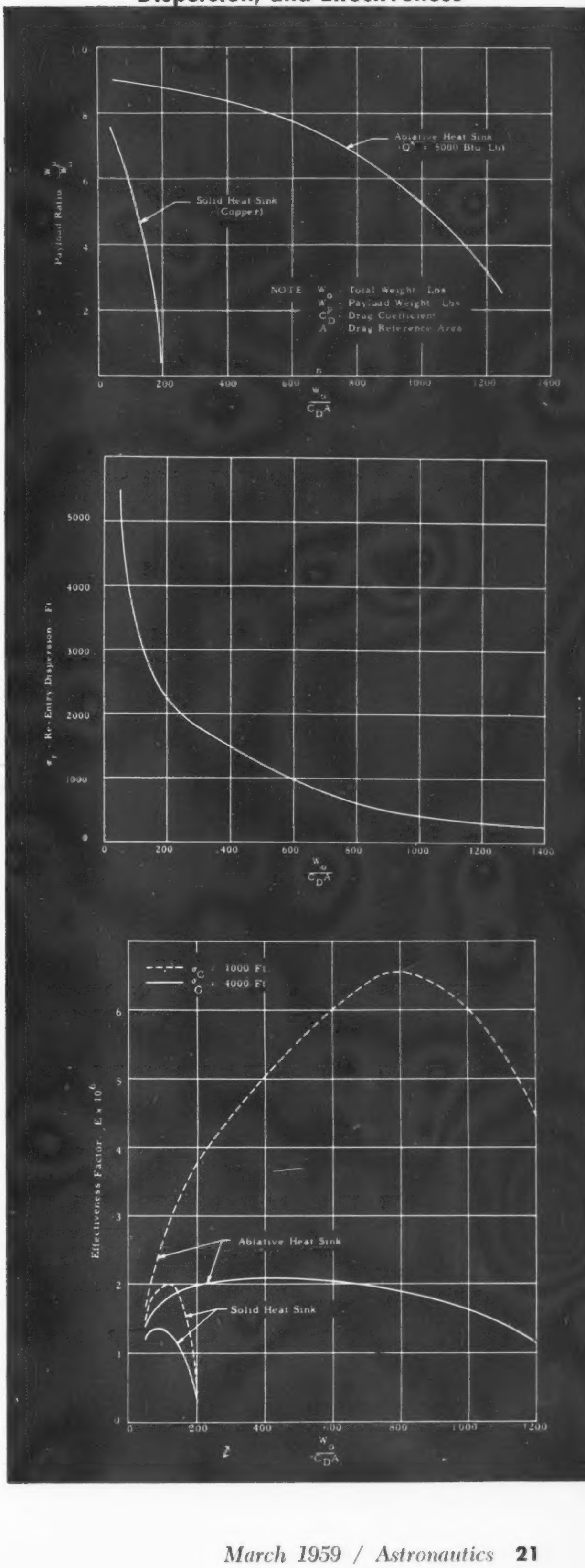
Peak Heat Rate

The significant period of heating during re-entry is nearly constant for a fixed re-entry angle and velocity. But, as the ratio of initial weight to the product of drag coefficient and drag area (W_0/C_DA) increases, the *peak heat rate* during this period markedly increases. For low values of peak heat rate, the sink material behaves as a capacitor, i.e., the temperature distribution normal to the surface into the interior of the sink is relatively constant, but, as the peak heat rate increases, the temperature becomes nonuniform, with the maximum temperature, of course, at the outer surface.

Finally, a maximum heat rate will be reached when even the surface of a semi-infinite sink would reach the material melting temperature. A practical limit to the peak heat rate in many cases occurs when a material thickness of but a few inches is required. Thus, a solid nonmelting heat sink is heat-rate limited for nose-cone applications at long ranges.

It should also be noted that a given transition Reynolds number is reached earlier in the heating cycle as W_0/C_DA increases; and therefore more of the heating will be caused by a turbulent boundary layer—thus further empha- (CONTINUED ON PAGE 98)

Re-Entry in Terms of Payload, Dispersion, and Effectiveness



Re-entry heat transfer

Analysis of heat-transfer dynamics shows how ablating shields for re-entry vehicles provide heat protection and freer guidance and control

By Lester Lees

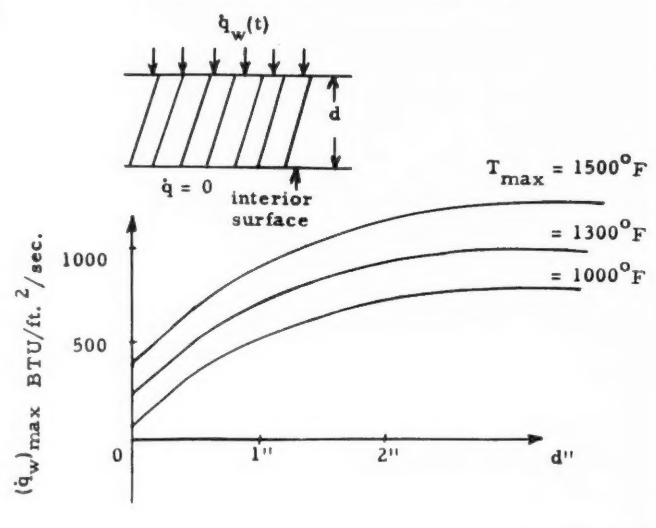
CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF.

IN HIS discussion of the general nature of the re-entry problem on page 20, George Solomon brings out the strong interaction between the coolant system and over-all performance of a ballistic missile. This type of interaction is important also for spacecraft entering a planetary atmosphere, particularly in determining the maximum permissible entry angle and the width of the "entry corridor." It may therefore be helpful to review briefly our present understanding of the heat-transfer mechanisms involved in various possible coolant systems.

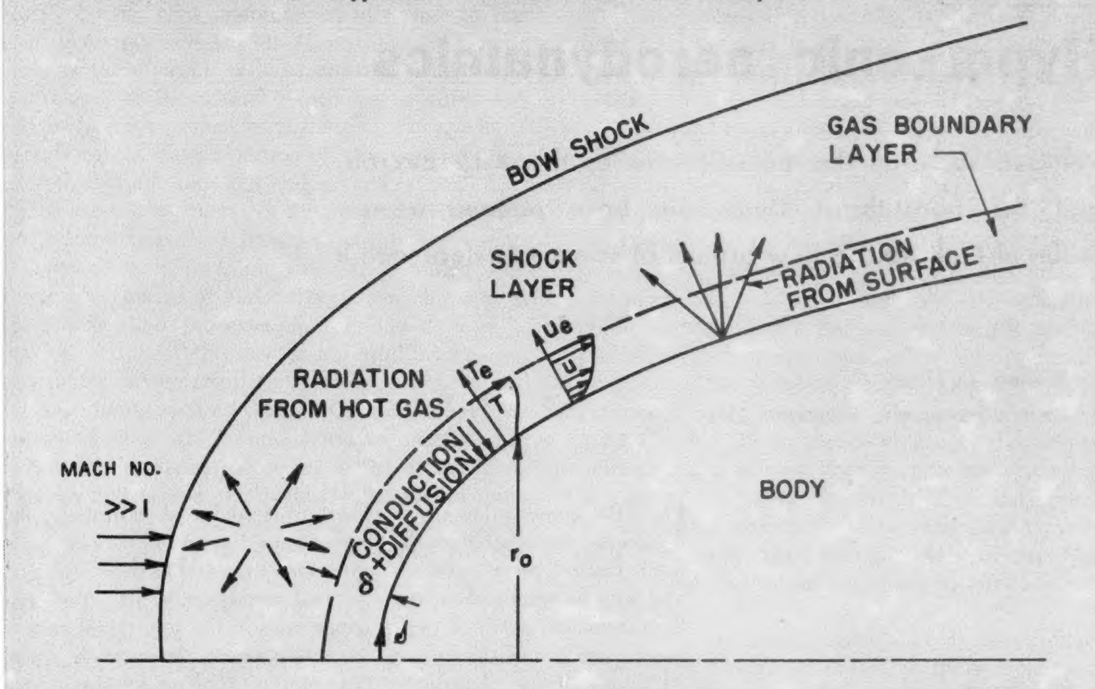
At altitudes above 100 miles, the atmosphere is so rarefied that gas molecules striking the surface of a moving vehicle have practically no previous knowledge of the vehicle motion. Under these conditions the surface heat-transfer rate ($\dot{q}_w$) at hypersonic speeds is approximately $(a/2)\rho_\infty V^3$, where a is an energy accommodation coefficient, ρ_∞ is ambient gas density, and V is flight velocity. If

Lester Lees is professor of aeronautics at CalTech's Guggenheim Aeronautical Lab, where he shares direction of the hypersonics research group with Clark Millikan. He is also a consultant on aerodynamics and heat transfer to Space Technology Labs. After receiving an M.S. in aeronautical engineering from MIT in 1941, he held research positions with AMC, Wright Field and NACA Langley Aeronautical Lab and, from 1946 to 1943, when he joined CalTech's staff, taught aeronautical engineering at Princeton Univ., where he was in charge of supersonic and hypersonic research.

Heat Transfer for a Rectangular Slab



Hypersonic Flow Over a Blunt-Nosed Body



such a relation persisted to lower altitudes, the heat-transfer rates and total heat energy transferred to the vehicle surface would indeed be catastrophic.

Fortunately, almost all of the critical heat-transfer problems during entry occur in the continuum flow regime—at least for Earth, Mars, and Venus. Molecules reflected from the surface of a blunt-nosed body collide with the new, oncoming molecules and build up a distinct bow shock wave, a "shock layer" of hot, partly dissociated and ionized gas between the shock and the body surface, and a boundary layer across which the gas temperature drops rapidly to its value at the surface, as depicted by the illustration above. This viscous layer acts as an effective heat-transfer screen, and the surface convective heat-transfer rate is only a small fraction of the maximum "free-molecule" flow value of $\frac{1}{2}\rho_\infty V^3$.

When the boundary layer is laminar, heat energy is transported across streamlines by ordinary heat conduction and by mass diffusion of atoms and molecules carrying chemical enthalpy appropriate to their respective heats of formation. At the same time, recombination reactions occur in the boundary layer, and the constituents of "air" may react chemically with vaporizing sur- (CONTINUED ON PAGE 60)

Table of Equations

$$\dot{q}_w \sqrt{R_0} = 21.3 \sqrt{\rho_\infty}\, V^3 (1 - h_w/h_{se}) \quad (1)$$

$$\sigma = \rho_\infty/\rho_0 = 2\beta\Delta \sin\theta_E/\rho_0\, g\, (\log_e VE/V) \quad (2)$$

$$\dot{q}_w \sqrt{R_0} \sim (\Delta \sin\theta_E)^{1/2} \left(\log_e \frac{V_E}{V}\right)^{1/2} V^3 \quad (3)$$

$$(\dot{q}_w)_{\max} \sqrt{R_0} \sim \Delta^{1/2} (\sin\theta_E)^{1/2} V_E^{\,3} \quad (4)$$

$$Q \sqrt{R_0} \sim (\Delta \sin\theta_E)^{-1/2} \left(\frac{1}{2}\frac{W}{g} V_E^{\,2}\right) \quad (5)$$

$$\dot{q}_s = \rho_e u_e C_H\, \Delta h - (\rho v)_w L \quad (6)$$

where

$$\Delta h = \sum_i (K_i)_e (h_{ie} - h_{iw}) + \frac{u_e^{\,2}}{2} + (K_o)_e\, \Delta Q_{Eo}$$

NOTE: Subscripts have the following meanings: e, conditions at the outer edge of the boundary layer; *E*, entry conditions at an altitude of 400,000 ft; *i*, refers to gas-liquid interface; w, evaluation at the surface; and ∞, ambient conditions.

Part I

Hypersonic aerodynamics

Vehicles such as the ballistic missile, the X-15 aircraft, and the boost-thrust Dyna-Soar have opened a new realm of flight and a new branch of science to deal with it

By Wallace D. Hayes

PRINCETON UNIVERSITY, PRINCETON, N.J.

Wallace D. Hayes is professor of aeronautical engineering at Princeton Univ. After receiving a Ph.D. in physics at CalTech in 1947, he spent a postdoctorate year at Princeton, three years on the faculty of applied mathematics at Brown Univ., a year on a Fulbright scholarship at Delft Technical Univ., and two years on the staff of ONR's London office before joining the Princeton faculty in 1954. Dr. Hayes worked for Consolidated Aircraft Corp. in 1939, and has been associated with the aircraft and missile industry in various capacities much of the time since then. He has been a consultant to Space Technology Labs and is at present a consultant to Aeronautical Research Associates of Princeton.

IN THE present-day development of vehicles of extremely high velocity, much attention has been focused upon re-entry bodies of the ballistic type, with the configurations intended to have high drag and with no requirement of developed aerodynamic lift. Such configurations are not high-performance ones in the traditional aerodynamic sense, and the concept of aerodynamic cleanness is absent. Although these configurations pose ample problems for the aerodynamicist in the control of heat transfer and of stability, the classical challenge of reducing drag while maintaining lift is missing.

The aerodynamicist can take heart, however, for the more important high-velocity configurations of the future are likely to be high-performance ones. To avoid high accelerations and control point of landing with a re-entering vehicle, or to obtain appreciable range with a vehicle at well below satellite velocity, the vehicle must develop lift without too great a cost in drag. The X-15 research airplane and the Dyna-Soar project are examples in this direction.

Challenge to Aerodynamicist

The requirement of high performance at hypersonic speeds presents to the aerodynamicist a challenge both old and new—to solve problems which have been with him since the first glider was designed as well as those which have arisen out of the new basic science of hypersonic flow. In this article we discuss the more important concepts of hypersonic aerodynamics. A number of simplifying assumptions are made to avoid clouding important points. For example, the Earth is assumed to be nonrotating and spherical, and the atmosphere to be thin in comparison with the Earth's radius. Accurate computations do not admit such simplifying assumptions.

Hypersonic aerodynamics, as the name implies, concerns flight in an atmosphere. Let us look then for a moment at the Earth's atmosphere, as it is the one of most immediate concern.

A distinguishable surface called the tropopause separates our atmosphere into two parts. The lower part is the troposphere, about 7 miles thick, and characterized by the turbulent processes we term weather. The upper part is the stratosphere, characterized by small temperature gradients and little turbulence.

For aerodynamic purposes, the atmosphere is simply 80 per cent diatomic nitrogen and 20 per cent diatomic oxygen. It is possible that local zones of the atmosphere have sufficiently high concentrations of dissociated molecules to affect the thermodynamic properties of the air. For the most part, however, the proportion of species other than neutral diatomic nitrogen and oxygen is small.

The other constituents of the atmosphere are primarily argon, carbon dioxide, and water vapor. One aerodynamic function which these constituents or ionized species of various types may have is to affect relaxation processes in the flow-field of a moving body. If the flow is an equilibrium one, their effect is very small.

Constituents such as CO_2, H_2O, and O_3 have an important effect which is nonaerodynamic; they act in radiative exchange processes in the atmosphere. Pure N_2 and O_2 are relatively transparent to most of the spectrum of electromagnetic radiation. Radiative exchange processes are responsible for the temperature distribution in the high stratosphere and for the phenomena of ionized layers.

Within the flow-field of a body moving through air at extremely high speeds—of the order of Mach 10 or above—the air molecules do not all remain diatomic. There is a certain degree of dissociation of the gas, and the energy absorption in the dissociation process is responsible for marked deviations from the perfect gas laws. Thus, in general, the working fluid in hypersonic aerodynamics may not be considered to behave as a perfect gas.

With what types of vehicles are we concerned? The illustration at bottom designates four salient types in terms of characteristic trajectories. A high-speed vehicle must take off or be launched, must accelerate to operating speed, must carry its payload over the operating range of the vehicle, and must make a terminal maneuver which may include landing. For a ballistic missile, the critical portion of the mission from an aerodynamic point of view is the terminal re-entry phase, with its extreme heating problem. For a vehicle which must develop lift to attain its range, the critical portion of the mission from an aerodynamic point of view is the portion in which lift is developed. Vehicles with trajectories of intermediate type or of a type combining characteristics of the four cited in the illustration are possible, but they will not be discussed.

In purely ballistic re-entry into the atmosphere from space, the kinetic energy of the vehicle must be dissipated against drag over a relatively short distance and high (CONTINUED ON PAGE 72)

TABLE OF EQUATIONS

Lift $(L) = W(1 - V^2/g\mathcal{R})$ (1)

Boost-Glide Range $(R) = \dfrac{1}{2}\left(\dfrac{L}{D}\right)\mathcal{R} \ln\left(\dfrac{1}{1 - V_0{}^2/g\mathcal{R}}\right)$ (2)

Sustained-Propulsion Range $(R) = \dfrac{(L/D)IV \ln(W_0/W_1)}{1 - V^2/g\mathcal{R}}$ (3)

Angle of Bank (γ) . . . $\dfrac{\tan\gamma = (V^2/g\mathcal{R})\tan\theta}{1 - V^2/g\mathcal{R}}$ (4)

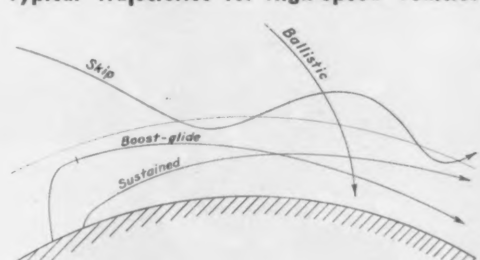
. . . $\dfrac{\cos\gamma = 1 - V^2/g\mathcal{R}}{n}$ (5)

Total Load Factor $(n) = \dfrac{L}{W} = \sqrt{1 - \dfrac{2V^2}{g\mathcal{R}} + \left(\dfrac{V^2}{g\mathcal{R}\cos\theta}\right)^2}$ (6)

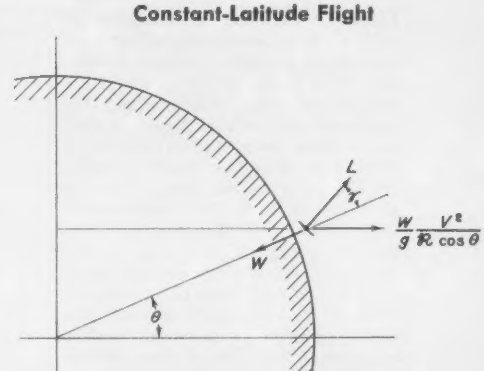
Velocity after Turn $(V) = V_0 \exp\left(-\dfrac{D}{L}\phi\right)$ (7)

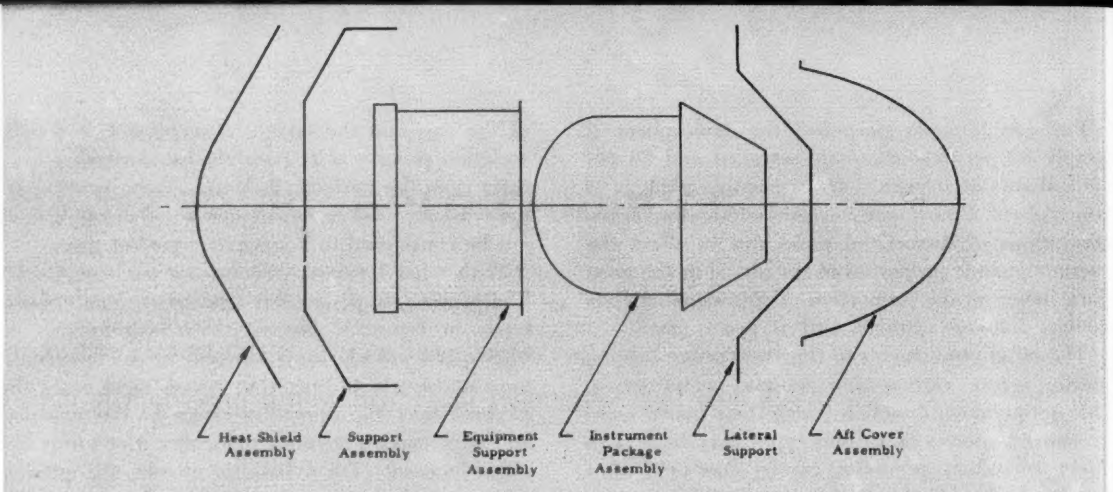
Vehicle Wt $(W) = W_0 \exp\left[-\dfrac{D}{L}\,\dfrac{\mathcal{R}\sqrt{\left(1 - \dfrac{2V^2}{g\mathcal{R}}\right)\cos^2\theta + \dfrac{V^4}{g^2\mathcal{R}^2}}}{IV}\,\phi\right]$ (8)

Typical Trajectories for High-Speed Vehicles



Constant-Latitude Flight





Schematic of Typical Structural Modules for Re-Entry Vehicles (Not to Scale)

Design and fabrication of a re-entry vehicle

Modular design founded in standard airframe practices gave versatility, simplicity, and speed to Atlas-Thor re-entry vehicle program

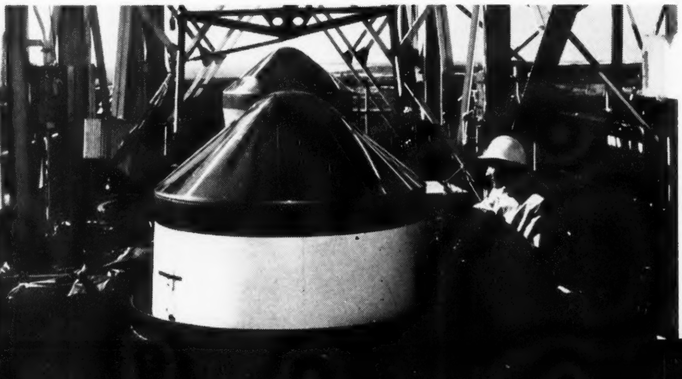
By Leon L. Farnham

GE MISSILE AND SPACE VEHICLE DEPT., PHILADELPHIA, PA.

Leon L. Farnham is manager of vehicle engineering—including design, stress analysis, structures-laboratory work, and drafting—for GE's Missile and Space Vehicle Dept. He graduated magna cum laude in civil engineering from Tufts College in 1943, and, after two years of active duty in the Navy, completed the postgraduate course in naval architecture at the Univ. of Michigan in 1946. Before joining GE in 1955, he did stress analysis on airframes and structural design for Glenn L. Martin and Chance Vought, working with the latter company as structures project engineer on the F7U-3 Cutlass aircraft and Regulus II missile.

WITH Thor operational and Atlas nearly so, it should be of interest to review the approach taken to the design and fabrication of the re-entry vehicle for these ballistic missiles. As a matter of form, we shall say that a ballistic missile re-entry vehicle (R/V hereafter) is that portion of a ballistic weapon system which transports the payload through space to its intended target area, provides protection during its plunge into the Earth's atmosphere at more than 10,000 mph and, having survived tremendous heat, shock, and deceleration, places the payload on target properly armed and fuzed for maximum effect.

Atlas and Thor both use this nose cone, an outgrowth of the GE modular development program.



The broad requirements set up for a R/V in the ballistic missile program can be summarized as follows. It must be:

1. Compatible with the remainder of the weapon system.
2. Of minimum weight.
3. Suited and conducive to proper environmental conditions for the payload.
4. Economically feasible to build, transport, store, handle, and service.
5. Able to survive re-entry into the Earth's atmosphere, taking into account the atmospheric variations of temperature and pressure in all the likely target areas on the Earth's surface.
6. Aerodynamically stable within the limits of systems-accuracy and payload-operating requirements.
7. Able to arm and fuze the payload within the required altitude limits.

This discussion will center on efforts in the areas coming under Points 2 and 4 above by GE's Missiles and Space Vehicles Dept., describing some aspects of the heat protection and structural concepts from design and fabrication viewpoints.

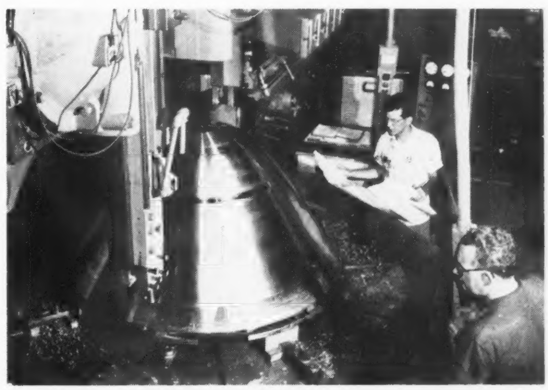
At program inception, it quickly developed that the R/V structural design must feature flexibility sufficient to accommodate many variations of R&D instrumentation, and must retain the ability to convert easily and quickly to an operational configuration. Estimates of the total number of R&D vehicles required revealed that "one-of-a-kind, one-at-a-time" concepts had to go, and that some design solution had to be found which would permit relatively large numbers of R/V's to be constructed, then modified quickly and easily to obtain flight data in the many technical areas under attack, such as aerodynamics, thermodynamics, control, instrumentation, power supplies, etc. In effect, an extensive R&D flight program had to be conducted to obtain experimental data in all the required technical areas, and results from the program had to be fed into the operational design at the earliest possible date.

Modular Approach Provides Flexibility

Design studies showed that a modular concept of structure would provide the required flexibility and economy, and would be capable of accepting the many design changes which were felt to be inevitable in view of the state of the art in the various technical areas. The modular approach took this form:

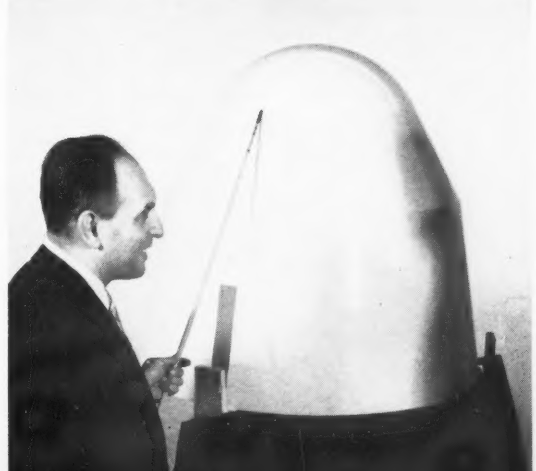
1. The R/V would be made up of several "modules," such as the early one shown at top right of this page.
2. These modules would (CONTINUED ON PAGE 57)

This early version of a re-entry vehicle structural module, with pneumatic reservoir incorporated, employed 2024, 7075, and 6061 aluminums and 4130 steel heat-treated to 180,000 psi.



An early version of a heat shield receives initial machining on Gidding and Lewis vertical boring mill.

This re-entry vehicle, showing the sophistication of current nose-cone design, is similar to the one that re-entered the atmosphere successfully in last July's Thor-Able 6000-mile flight.



Heat protection for re-entry vehicles

Heat sinks, radiation cooling, ablation, and transpiration cooling all show promise, but developing materials with the unique combination of properties required still poses a number of major problems

By Norris F. Dow

GENERAL ELECTRIC CO., PHILADELPHIA, PA.

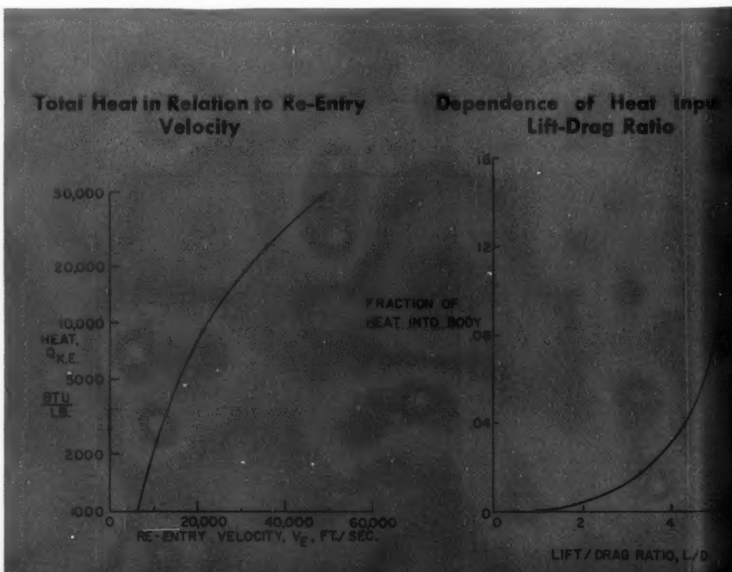
Norris F. Dow is now a specialist in structural systems with the Aerosciences Lab of GE's Missile and Space Vehicle Dept., concerned with heat-protection systems, materials, and structures for advanced design ICBM nose cones, and re-entry vehicles. A 1939 graduate of Brown Univ. with a B.S. in aeronautical engineering, he was with the NACA Langley Aeronautical Laboratory Structures Research Div. for 16 years, the last two years as head of the Airframe Components Branch, with responsibility for research in the fields of strength, elevated temperature, and stresses and deflections of aircraft structures, and for the preliminary feasibility study and design of the X-15 structure. He joined GE in 1955.

RECOVERED nose cones like the one shown by President Eisenhower on television demonstrate that heat-protection problems have been solved for ballistic missiles. The problems are, however, so much more difficult for manned re-entry—particularly for severe re-entries from satellites and manned space vehicles—that one wonders whether there can be any latitude to their solution.

Will re-entry have to be just right, and the men inside athletic eggheads? Or are there potential margins, so that average men may some day travel in space and return?

The heat-protection system is a major factor in determining how critical the re-entry is. Only if the heat-protection margin is ample can other factors such as maximum accelerations be maintained at reasonable levels. Accordingly, let us consider the problems of re-entry heat protection to determine whether ample margins potentially exist.

Re-entry heat is produced if the atmosphere is used as a brake to slow down from the velocities of space travel. The energy of the body is changed into heat, and the heat-protection system must keep that heat from the interior of the body. At the start of re-entry, total energy is approximately equal to $Q_{K.E.} = (V_E)^2/_{50,000}$—where $Q_{K.E.}$ is the heat equivalent of the kinetic energy in Btu per pound



of vehicle weight, and V_E is the velocity at re-entry, expressed in fps. This relationship is plotted in the graph on the opposite page.

Perhaps the slowest speed of interest is for a low-altitude satellite —about 26,000 fps. Re-entry velocities after a coasting trip from the moon approach approximately 36,000 fps, or escape velocity. This velocity has an added significance, for it is the maximum velocity at which the vehicle can re-enter tangentially and start to circle the Earth at constant altitude without subjecting the occupants to more than 1 g. This 1 g is attained by coming in upside down and using aerodynamic "lift" to keep from flying off into space again.

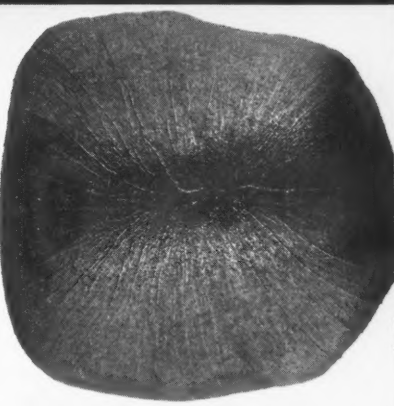
Because some such maneuver must be used if exorbitant accelerations are to be avoided, and because the average man will probably complain if subjected to more than about 2 g for any length of time, the likelihood is small of re-entry velocities from powered space flights being much in excess of 50,000 fps for any true passenger-carrying vehicles. Accordingly, a look at the equation or graph on the opposite page indicates the total heat generated during re-entry may not be expected to exceed 50,000 Btu/lb of vehicle weight.

Maximum Fraction of Heat

Not all the heat generated is transferred to the vehicle, most of it being left behind as hot air. The maximum fraction of the heat reaching the body is one-half, with the actual fraction much less, particularly for low lift-to-drag (L/D) ratio vehicles. The graph on the opposite page shows that for a lift-to-drag ratio of 2, for example, only about $^1/_2$ of 1 per cent of the kinetic energy will show up as heat in the body.

A lift-to-drag ratio of 2 is convenient for study. At this ratio for the 36,000-fps re-entry, the net outward-acting acceleration from the inverted "lift" is 1 g, the drag is 1 g, and the passengers will not be too uncomfortable. (To maintain 1-g drag would require the manipulation of some sort of drag brake.) So, for evaluating heat-protection systems, let us use an L/D = 2 body and consider three re-entries—at 26,000 fps (from a satellite), at 36,000 fps (from a moon glider), and at 50,000 fps (from powered spaceships).

The total heat inputs encountered would then be 68, 130, and 250 Btu/lb of vehicle weight, respectively. (CONTINUED ON PAGE 82)



Stony (top) and iron meteorites are compared in these Chicago Natural History Museum photos.

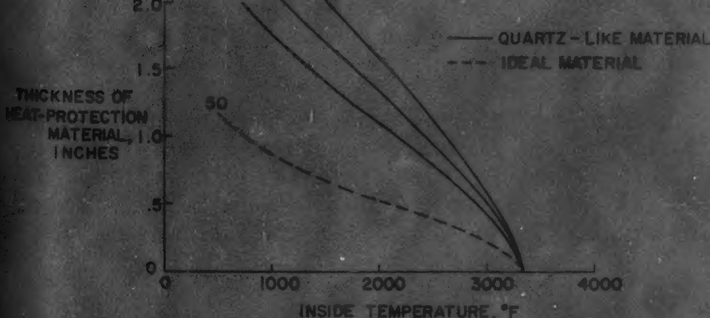
Heat-Sink Capacities

Material	Heat required to raise to melting temperature (Btu/lb)
Copper	150
Aluminum	280
Molybdenum	420
Tungsten	770
Beryllium	1600
Graphite	4100

Melting or Subliming Temperatures of Refractories

Material	Melting or subliming temperature (Deg F)
Fused quartz	3038
Molybdenum	4748
Magnesia	5072
Tungsten	6100
Graphite	6870
Hafnium carbide	7520

Thickness of Quartz-Like Material Needed to Maintain Inside Temperature for Typical Hot-Spot Conditions During Re-Entry

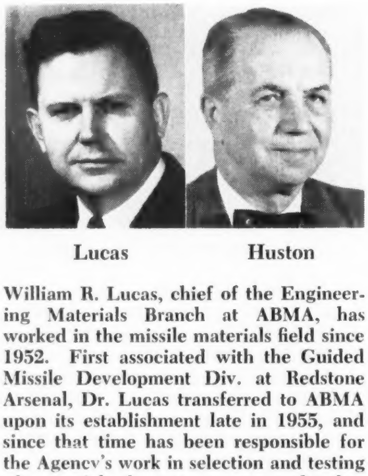


Planning a re-entry and recovery test program

Demand for reliable re-entry vehicles and recovery techniques grows with approach of manned space flight. . . Here's how ABMA tackled the job of insuring successful Jupiter nose-cone re-entry and recovery

By William R. Lucas and Myron E. Huston

ARMY BALLISTIC MISSILE AGENCY, HUNTSVILLE, ALA.



Lucas Huston

William R. Lucas, chief of the Engineering Materials Branch at ABMA, has worked in the missile materials field since 1952. First associated with the Guided Missile Development Div. at Redstone Arsenal, Dr. Lucas transferred to ABMA upon its establishment late in 1955, and since that time has been responsible for the Agency's work in selection and testing of materials for nose cones and other missile components. Dr. Lucas was graduated from Memphis State Univ. in 1942 and received his Ph.D. degree from Vanderbilt Univ. in 1952. His experience includes teaching and research in chemistry and metallurgy.

Myron E. Huston, project supervisor for the ABMA recovery program, coordinates Army efforts with industry and other services contributing to the recovery project. He joined the Army missile team at Redstone Arsenal in 1952, and was named supervisor of ABMA's recovery program in June 1956. His career includes service with the Navy in WWI, with OSS during WWII, and with NACA.

FLIGHT TESTING of a re-entry nose cone is actually the culmination of a carefully planned re-entry and recovery test program. Of the many problems facing the development team of the Jupiter IRBM, for example, perhaps the toughest was the aerodynamic heating problem. An appreciation of the magnitude of the problem justified the planning of a comprehensive re-entry and recovery program early in the development period.

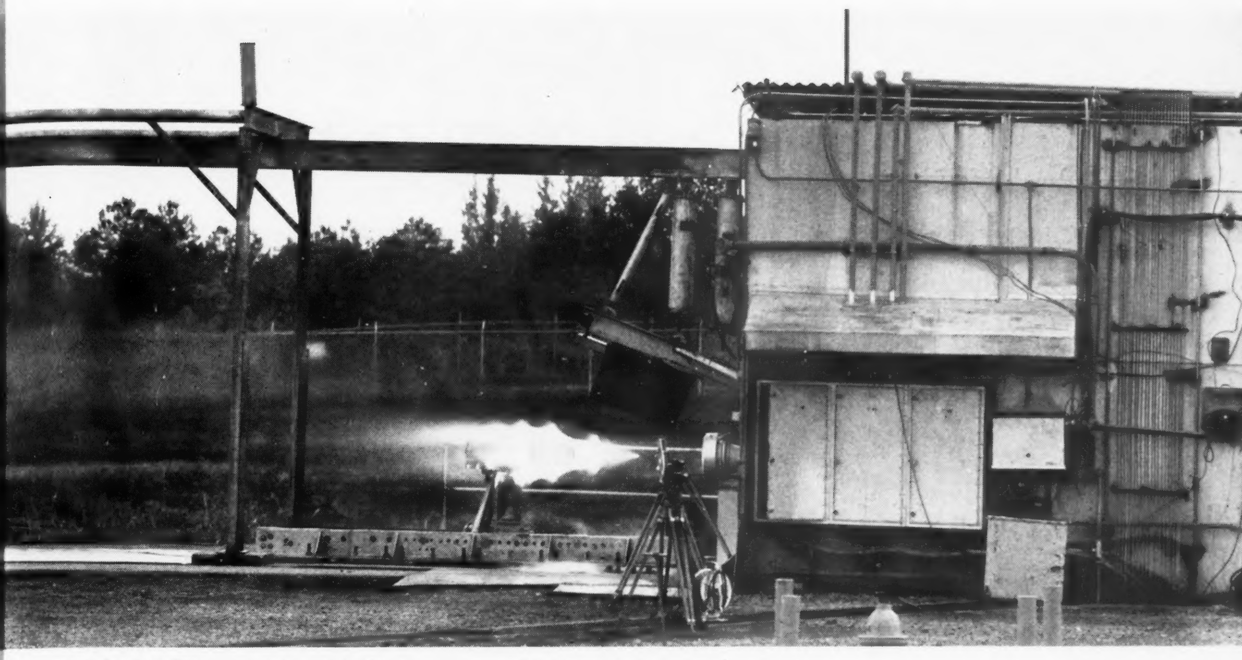
With configuration established and the extent of the aerodynamic heating problem assessed analytically, the re-entry part of the program became a five-step task. This order is not necessarily chronological, since work in several areas was being, and should be, accomplished concurrently. The five steps are as follows:

1. Preliminary selection of materials and techniques for construction of the nose-cone insulative covering
2. Simulation testing
3. Scale-model testing on a flight vehicle
4. Pre-flight inspection of full-scale cone
5. Instrumentation for evaluation of response of thermal insulation to re-entry environment

A preliminary selection of materials is made on the basis of thermal properties and stability at high temperature. Materials of many compositions, as well as a wide range of application techniques, must be screened to find the ones which show the most promise for the program in question. Samples constructed of promising materials must then be put to test in aerodynamic heat simulation facilities for screening on the basis of performance characteristics.

Several methods exist for simulation testing. The exhaust of a rocket motor is one of the most satisfactory devices for simulating re-entry of current IRBM nose cones. Several rocket motors—graduated to provide the most information with the least cost—are used at ABMA for systematic screening of potential nose-cone materials.

Initial screening is done with a rocket motor referred to as the 4-HT. This motor, pictured on the next page, enables us to test a flat plate 4 in. square at a heat flux of 1.8×10^5 Btu/ft^2 hr and an exit gas velocity of 6700 fps. After the motor has been started, the test sample is thrust into the blast for a prescribed time. The



ABMA 164-HT materials test facility permits evaluation of nose-cone shapes.

response of the sample is evaluated through television observation during the test, from heat transfer data during the test, and, finally, from examination in the laboratory after the test.

Evaluating Nose-Cone Shapes

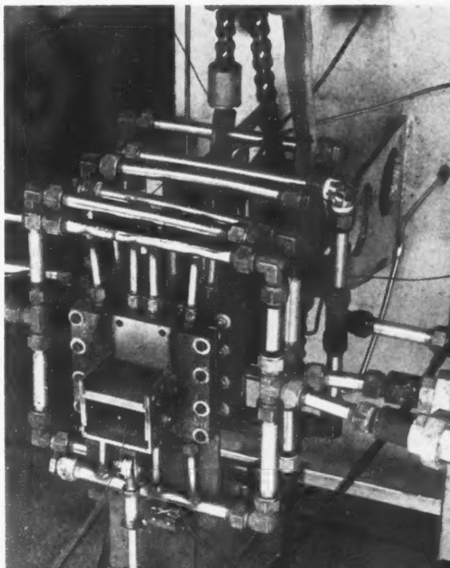
Nose-cone shapes can be evaluated in the setup shown above. The rocket motor in this facility provides a heat flux of approximately 0.9×10^6 Btu/ft^2 hr if the radius of the nose cone is 2 in. Exit velocity of this motor is about 6700 fps. Usually, the hemispherical portion of the nose cone is tested in the interest of saving material and time. However, cones as large as 15 in. in base diam can be tested.

Other rocket motors are available for other test configurations and conditions. One facility is available for testing the full-scale nose cap of the Jupiter missile under heat flux conditions which very closely simulate those encountered in re-entry.

After extensive simulation testing of a selected material, scale models of nose cones may be constructed from the material and flown on a test vehicle. This step, although not absolutely necessary, is very valuable and should be included in any program where it is possible to use a flight-test vehicle less expensive, or available earlier, than the carrier vehicle. In the case of the Jupiter, a modified Redstone proved to be an excellent test vehicle.

Any defects showing up in the flight test can be lessened or eliminated prior to construction of a full-scale flight nose cone.

The completed nose cone is thoroughly inspected optically and by X-ray before it is used. Every defect (CONTINUED ON PAGE 88)



4-HT rocket motor, used for simulation testing of re-entry nose-cone materials.

Dynamic stability of re-entry vehicles

Extension of available aerodynamic theory adequately describes linear oscillatory behavior of hypersonic flight and re-entry vehicles

By Murray Tobak

NASA AMES RESEARCH CENTER, MOFFETT FIELD, CALIF.

Murray Tobak is a staff member of the High-Speed Research Div. at NASA's Ames Research Center. He has engineering degrees from the Univ. of Calif. and Stanford Univ. Since coming to Ames in 1948, he has specialized in studies of dynamic stability of high-speed aircraft and, more recently, of re-entry vehicles.

TO DEVELOP ballistic missiles and recoverable manned space vehicles, we must not only study a wide range of new problems, but also reinvestigate familiar ones in new circumstances. A problem of the latter kind is the dynamic behavior of re-entry vehicles during descent through the atmosphere and return to earth.

Aerodynamicists, of course, have been interested in the dynamic behavior of airplanes for a long time, and the mathematical foundations for studies in this field are broad and well established. Indeed, they are sufficiently broad to encompass the dynamics of re-entry vehicles, as well as airplanes, without essential change in form.

It is only the circumstances that have changed, and these may be characterized very simply: Two fundamental quantities, which in airplane studies could be considered constants, now become significant variables. These quantities are the atmospheric density (ρ), which changes by roughly a factor of 10 in every 10 miles of altitude change, and the vehicle's forward speed (V), which can undergo a reduction from the order of satellite speed (18,000 mph) to transonic or subsonic speed (700 mph) by the time the vehicle nears the ground.

Let's consider how large and rapid changes in density and velocity can affect the dynamic motion of a vehicle as it passes through the atmosphere. Assume that, as the vehicle enters the atmosphere, its longitudinal axis is misaligned from the flight path by the angle of attack (α) and that initially the vehicle is not rotating about its center of gravity. For simplicity, assume further that the vehicle develops no aerodynamic damping. As the vehicle begins its descent through the rarefied upper atmosphere, the absence of any appreciable drag enables it to descend for a considerable distance with virtually no loss of speed. The air then becomes more dense, however, so that dynamic pressure begins to build up.

In response to the angle of attack and the buildup of dynamic pressure, an aerodynamic turning moment develops, which, if stabilizing, i.e., tending to reduce the angle of attack, will cause the vehicle to begin to oscillate about its center of gravity. The magnitude of this aerodynamic turning moment per unit angle of attack builds up in direct ratio with the dynamic pressure. Just as with the oscillation of a spring continually being stiffened, the angle of attack oscillation will continually diminish in amplitude and increase in frequency so long as the dynamic pressure increases.

Meanwhile, however, drag also increases in direct ratio with dynamic pressure and begins to act as a powerful brake on the vehicle's velocity. Eventually, the vehicle slows down at a greater rate than the air density increases. Then the dynamic pressure does not grow continually, but reaches a maximum at some altitude, after which it begins to fall off.

At this point, in the absence of aerodynamic or auxiliary damping, the vehicle's oscillation will begin to diverge, just as the oscillation of a spring will diverge as it is relaxed. Allowed to go unchecked, the oscillation will continue to diverge until, at a low altitude, the vehicle enters terminal flight.

One of Two Things Can Happen

From this point, one of two things can happen. Depending on the vehicle's shape, mass, and initial entry angle, the dynamic pressure can either continue to diminish slowly, gradually approaching a constant value as the vehicle nears the ground, or it can take on a minimum value and then increase slowly, again approaching a constant value. The first of these alternate histories is typical of vehicles that enter the atmosphere at very steep angles, whereas the second can occur with relatively light vehicles that enter at small flight-path angles.

Our concern here will be principally with vehicles of the latter type. Therefore we assume that the dynamic pressure increases slowly in the terminal phase, so that, with the vehicle's aerodynamic spring increasing again, its oscillation amplitude will be convergent in this last altitude range.

Notice that in the absence of aerodynamic damping, the sequence just described—consisting in turn of convergent, then divergent, and then again convergent oscillations—does not involve energy dissipation or accumulation through a damping mechanism. The mechanism is instead merely the alternate stiffening and relaxing of the aerodynamic restoring moment in accordance with the dynamic pressure history.

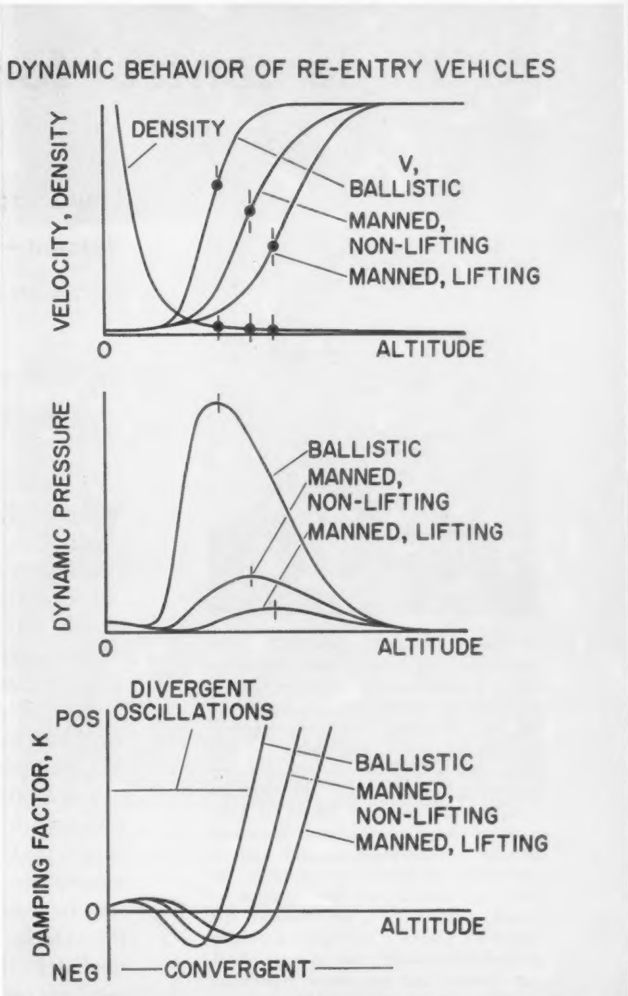
The vehicle's oscillatory behavior will thus depend strongly on the type of trajectory it follows, since the trajectory determines the dynamic pressure history. The oscillation behavior will also be influenced by the vehicle's shape, since the shape determines the magnitude of aerodynamic damping that can be provided to help restrain the oscillatory divergence that otherwise would develop over the altitude span in which the dynamic pressure falls off.

Simon Sommer and the author have derived an expression which defines these dependencies in a concise way for the envelope curve of the oscillatory angle of attack ($\alpha_{env.}$). This expression

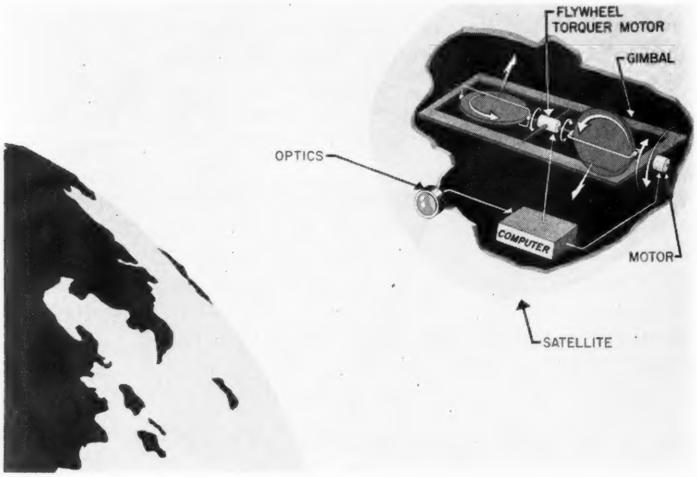
$$\alpha_{env.} = C \frac{u^{-K}}{q^{1/4}}$$

wherein q and u are, respectively, the dynamic pressure ($\frac{1}{2}\rho V^2$) and the vehicle's horizontal component of velocity, and K is a constant characteristic of the vehicle's aerodynamic damping properties. Note that for zero aerodynamic damping ($K = 0$) the vehicle's oscillatory amplitude history varies in inverse ratio with the history of q, as we have described. Positive values of K tend to reinforce and negative values to restrain the occurrence of divergent oscillations.

In addition to its use in describing a given vehicle's oscillatory history, the formula can be adapted to serve another purpose, (CONTINUED ON PAGE 66)



Orientation Control System



Attitude control for space vehicles

M. Baron T. George, assistant to the president for exploratory development, coordinates preliminary design programs and associated research for AVCO's Research Div. He received an engineering degree from McGill Univ. and a Ph.D. in aeronautical engineering from Cornell Univ. At Cornell, he did research aimed at integrating aerodynamic and structural factors in supersonic aircraft and investigated unsteady aerodynamic effects on airfoils at high angles of attack. At AVCO, Dr. George has worked on many interrelated problems of ballistic missile and re-entry satellite design, and has made significant contributions to the ICBM program.

Launching, flight in space, re-entry, and final descent—each of these typical flight phases bears on the design of attitude control systems

By M. Baron T. George

AVCO RESEARCH AND ADVANCED DEVELOPMENT DIV., WILMINGTON, MASS.

THE RE-ENTRY vehicle, for lowest possible weight of heat shield and structure, must be designed to enter the atmosphere in a particular attitude, as other articles in this issue make clear. But there are other reasons for having an attitude control system. A ballistic missile, manned satellite, and hypersonic rocket-boosted glider all undergo launching, flight through space, re-entry, and final descent. Each of these four phases must be considered by the designer when he tries to establish the need for an attitude control system. We shall look briefly at attitude control needed for each type of vehicle, and then particularly at orbital and re-entry control.

The ballistic missile re-entry vehicle need not have a fixed orientation during the space portion of its flight because it has no mission to perform at this time. However, as the vehicle encounters the atmosphere and is subjected to aerodynamic heating and loads, it may be necessary to adjust the attitude or control the oscillations of the vehicle. Another approach is to orient the re-entry vehicle immediately after it leaves the launcher and maintain this orientation until re-entry occurs. The final descent phase of a ballistic re-entry

vehicle appears anticlimactic, but maximum performance of the system requires attitude control right down to the ground. Fortunately, this portion of the flight falls within flight regimes for which there is substantial aerodynamic data.

A manned satellite, because of its human occupant, probably will require attitude control throughout the duration of flight. However, as our knowledge of man's reaction to space flight improves, it is possible that slow tumbling in orbital flight might be tolerable during periods when there is no need for observation.

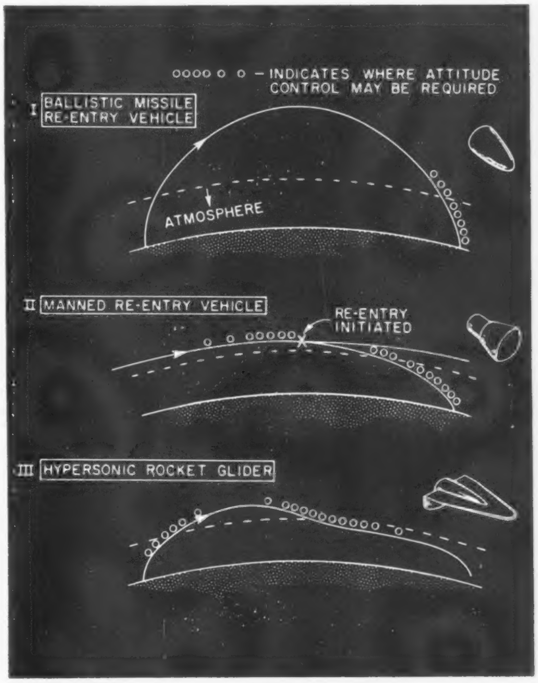
Re-entry of the manned satellite will be initiated at some preselected point by a perturbation of the orbit. This might be done by a sudden increase in aerodynamic drag, if the vehicle is traveling at an altitude where some residual atmosphere exists, or through the use of retro-rockets. The attitude of the vehicle must be adjusted just prior to the firing of these rockets in order that the change in the velocity vector will occur as required for landing in a specified region. Futhermore, this impulse must be maintained within certain directional limits throughout the firing period. Once the vehicle has lost a portion of its original velocity, it will begin its descent into the atmosphere.

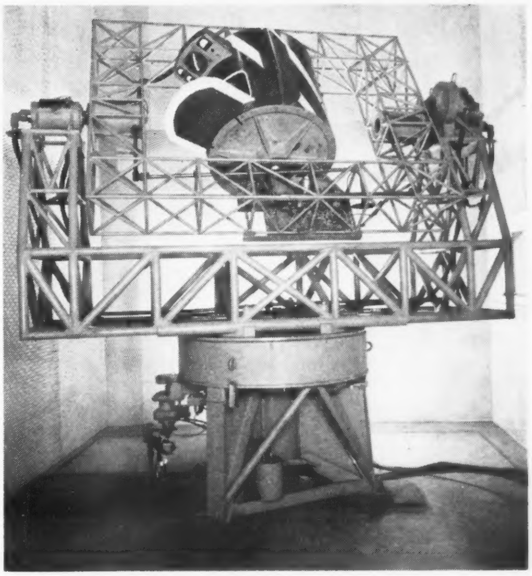
As with the ballistic missile, it will be necessary to insure a correct attitude for the re-entry portion of the flight. In the same class as the satellite vehicle, there can be placed the so-called satelloids, which are satellites intended to fly only in the outer fringes of the atmosphere for extended periods. In some cases, it may be possible to use aerodynamic surfaces to maintain the attitude of such a satelloid. Generally, a more powerful orientation system should be brought into play during those periods when propulsion is applied for the purpose of keeping the vehicle in its orbit. Here again there is the problem of insuring that the velocity increment supplied by the propulsion device does in fact act in a direction to maintain the orbit.

Hypersonic Rocket-Boosted Glider

Finally, we have the hypersonic rocket-boosted glider, as exemplified by the NASA X-15, due to fly shortly, and the proposed Dyna-Soar vehicle. When the glider is launched from another airplane, aerodynamic controls can maintain an attitude as long as dynamic pressure is sufficient. At some point, however, it will be necessary to supplement, and eventually take over, from the aerodynamic system with a reaction control system. Winged vehicles launched by large rocket boosters are likely to be in space when they separate from their boosters and therefore could not use aerodynamic controls. They would require (CONTINUED ON PAGE 106)

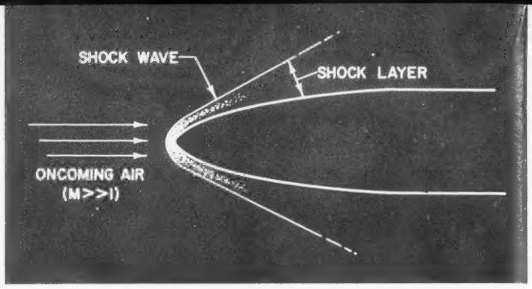
Requirements for Attitude Control





AVCO studies attitude control systems and missile guidance packages with this three-axis flight simulator.

Shock-Layer Ionization for Boost-Glide Vehicle



Communicating with the hypersonic vehicle

Penetrating the high-energy plasma about a hypersonic vehicle will require very high-frequency transmission with new integrated telemetry and communications equipment

By Stephen G. Homic and Richard L. Phillips

BENDIX AVIATION CORP. SYSTEMS DIV., ANN ARBOR, MICH.

Homic

Phillips

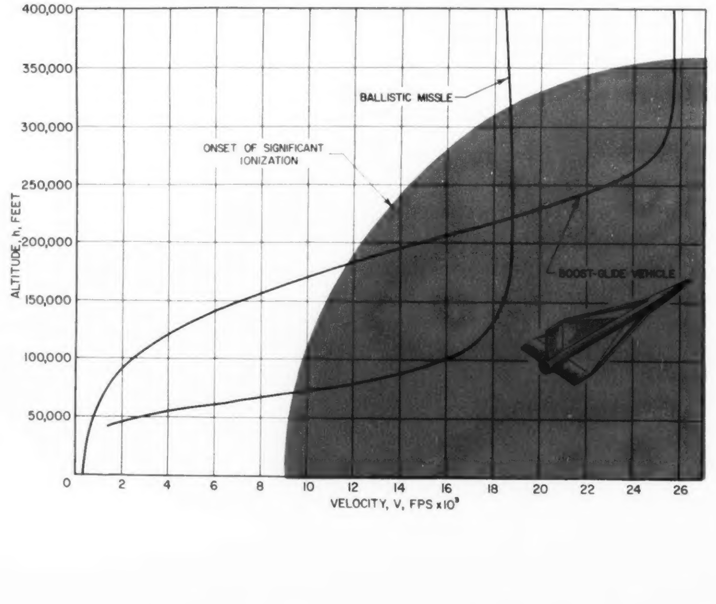
Stephen G. Homic is a staff engineer with Bendix Systems Div. He received a Sc.B. in engineering from Brown Univ. in 1951 and did graduate work in electrical engineering there until 1953. From then until 1957, when he joined Bendix, he was on the technical staff of Bell Telephone Labs, where he worked on the design and development of microwave antennas, antenna servo drives, and rf, if, and video circuitry. His work at Bendix covers electromagnetic propagation, communication systems, and network synthesis.

Richard L. Phillips is on the staff of Bendix Systems Div.'s Flight Sciences Dept., currently working on the aerophysics of radio propagation. Before joining Bendix, he was a member of the technical staff of Space Technology Labs Astrosciences Lab, where he participated in studies of manned satellite vehicle recovery.

THE PROBLEM of transmitting electromagnetic energy to and from a hypersonic vehicle is a fascinating one because of the necessity for combining the disciplines of hypersonic aerodynamics and electromagnetic theory. The existence of such a communication problem has often not been anticipated simply because adequate analysis of the problem required a knowledge of both subjects, and specialists in either field frequently failed to recognize the existence of problem areas.

Let us examine briefly the environment about a hypersonic vehicle. Consider a vehicle traveling at a speed on the order of Mach 20 at altitudes from 150,000 to 300,000 ft. As shown on

Electromagnetic Signal Attenuation with Boost-Glide Vehicle



page 36, a body traveling at hypersonic velocity will be preceded by an intense detached shock wave. This wave will compress the oncoming flow of air to very high pressures and, in so doing, heat it to extremely high temperatures. Depending on the combination of velocity and altitude, the temperature in the shock layer near the stagnation point of the vehicle can be as high as 6000 to 7000 deg.

In considering air at these temperatures, it is no longer valid to assume that the usual perfect gas relations hold. Under such conditions, air is dissociated into many species. One important decomposition product is NO, which has a very low ionization potential and emits electrons copiously. It therefore becomes necessary to take into account the ionization of molecules, the dissociation of oxygen and nitrogen molecules into their respective atoms, and the stripping off of the optical electrons of some atoms.

As a result of these high temperatures, then, the flow-field around the vehicle will contain an appreciable number of free electrons. Depending on Mach number and altitude, this concentration can be as high as 10^{15} particles per cc. As heated gas flows around to the sides of vehicle, the temperature as well as the pressure will decrease, and the lower temperature will result in recombination of some of the free electrons. Even at points far back on the vehicle, however, where the local flow-field temperature is only 50 per cent of the stagnation temperature, electron density may be of the order of 10^{10} particles per cc. This electron concentration corresponds to the intrinsic electron concentration of a silicon semiconductor.

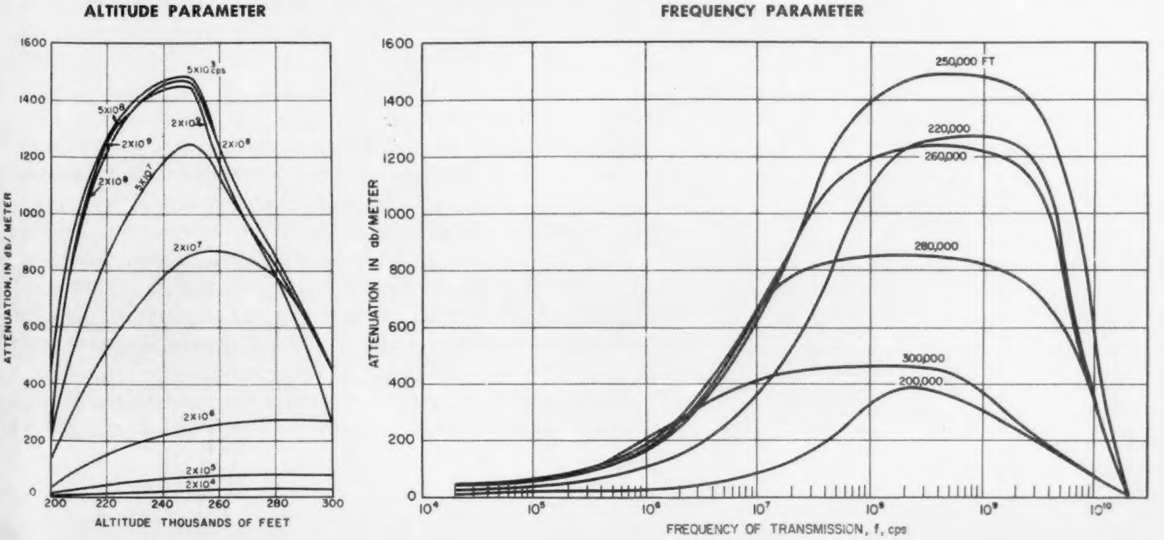
One can now begin to appreciate the problems of transmitting signals to or from a hypervelocity vehicle. That portion of radiated energy which has not been reflected will, of course, be propagated outward in the form of varying electric and magnetic fields. These fields can influence the charged particles which are in the medium surrounding the antenna.

Electrons Will Absorb Energy

It is generally assumed that the electrons, being much less massive than any of the negative or positive ions, are the only particles which will be influenced by electromagnetic energy. These electrons will be accelerated in various directions, and as a result will absorb some of the energy which is present in the radiation. Depending upon the electrical properties of the plasma, it may be that any attempt to transmit a signal from the vehicle to an outside receiver will be unsuccessful due to an excessive amount of signal attenuation.

Before turning attention to signal transmission, we need a further definition of the conditions of flight. The *shock layer* is that region between the body and the shock wave. The shock layer is *not* to be confused with the *boundary layer*, which is that region to which the effects of viscosity can be confined. The attenuation of electromagnetic radiation has sometimes been referred to as boundary-layer attentuation, but this is generally an incorrect designation of the problem, since the viscous boundary layer is usually cooler than the inviscid shock layer. The correct designation of the phenomenon, then, would be shock layer attenuation. (Under some conditions the temperature in the boundary layer can rise to (CONTINUED ON PAGE 92)

Shock-Layer Ionization for Boost-Glide Vehicle



Re-entry: Problems and progress

Efforts to solve one of the most fascinating engineering challenges of the day are leading us to the very frontiers of knowledge in such diverse fields as thermodynamics, physical chemistry, and aerodynamics

By Coleman duP. Donaldson

AERONAUTICAL RESEARCH ASSOCIATES OF PRINCETON, PRINCETON, N.J.

Coleman Donaldson received a B.S. in aeronautical engineering from Rensselaer Polytechnic Institute in 1942, and immediately joined NACA's Langley Aeronautical Lab, where he became head of the Aerophysics Section of the Gas Dynamics Lab. He left NACA in 1952 to attend Princeton Univ., where he received a Ph.D. in theoretical aerodynamics in 1954. In that year he also formed Aeronautical Research Associates of Princeton, a consulting firm specializing in gas dynamic and control problems of hypersonic re-entry and space vehicles. Dr. Donaldson has been a consultant to GE's Missile and Space Vehicles Dept. on problems of re-entry since 1956.

IT IS today a matter of almost common knowledge that a long-range ballistic missile or a satellite attains extremely high velocities, velocities of the order of 15,000 mph. It is not so much common knowledge that ballistic re-entry into the atmosphere at an enormous velocity does not by itself constitute a serious problem from the point of view of aerodynamic heating.

It is only when, in addition to the condition of high re-entry velocity, the designer is faced with the additional requirements of pinpoint accuracy on target or invulnerability to enemy countermeasures that the re-entry problem becomes a dilemma.

The dilemma is indeed a fascinating one. In attempting to uncover possible methods of resolving the problem, the gas dynamicist is led to consider many interesting new problems which lie at the very frontiers of our knowledge of thermodynamics, physical chemistry, and aerodynamics. While it would obviously be impossible for security reasons to discuss at this time the detailed status of the re-entry problem, it might be worthwhile to outline some of the broader aspects of the problem and the fields of research effort to which it has led.

Let us consider a vehicle entering the upper atmosphere traveling at a very high speed toward the center of the Earth. At such speeds, the air in the immediate vicinity of the missile has been slowed down in relation to the body by the action of either viscous or inertial forces and attains a high temperature. This heating is a result of the change in the directed kinetic energy of the air relative to the body, and is thus proportional to the square of the velocity of the vehicle.

An idea of how hot the gases in the vicinity of a re-entry vehicle can get may be obtained from the photo on the opposite page, which shows a blunt body traveling through a gas at Mach 12. The gas between the shock wave and the missile becomes so hot that it ionizes and gives off intense radiation. If a re-entry vehicle continues to travel at a high velocity as it penetrates deeper and deeper into the atmosphere, the scouring action of the hot gases immediately next to the body can heat the vehicle at enormous rates. Of course, the actual rate depends on the air density, so that the question of whether the vehicle will be destroyed or not depends on how far into the atmosphere it penetrates while still maintaining very high velocity.

Obviously, a light balloon which enters the atmosphere at high speed would not maintain its velocity to low levels in the Earth's

atmosphere, for a body of this type has very high drag and very little inertia, with the result that it is greatly slowed up while still at high altitudes. In this case, there is no serious heating problem, since the balloon is going slowly when it reaches altitudes where the air is dense enough to present a heating problem. Unfortunately, accurate prediction of the impact point of such bodies becomes almost impossible, since the balloon is at the mercy of atmospheric winds.

If one wishes to improve accuracy in predicting the point of impact, this can be accomplished by making the re-entry body denser or designing it so that it has a very low-drag coefficient. In this way, the body will maintain its high velocity throughout its flight and be less subject to the effects of atmospheric conditions.

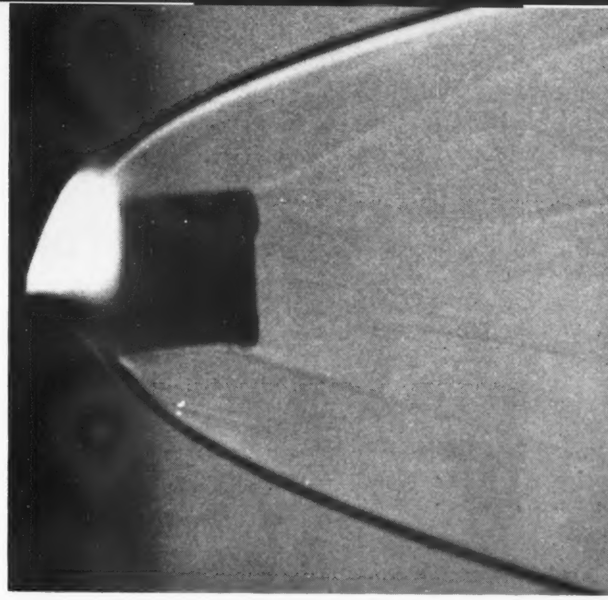
The designer's dilemma is now apparent. In order to achieve accuracy, high velocities at low altitudes are necessary, and this condition carries along with it the extreme heating problem.

In 1953, H. J. Allen and A. J. Eggers Jr. of the Ames Research Center of NASA published an excellent discussion of re-entry which showed that the prime parameter in the re-entry problem is W/C_DA, where W is the vehicle weight and C_D is the total missile drag coefficient based on the area A. The ratio W/C_DA can be shown to govern the ratio of missile velocity at any altitude h to its velocity at entrance, that is $V(h)/V_e$, and hence also governs the altitude of maximum heating.

The behavior of $V(O)/V_e$, the ratio of impact to entrance velocity, and the altitude of maximum heating h_m with W/C_DA for a body entering the atmosphere perpendicular to Earth's surface is shown in the graphs at right. As an example, it is noted that when $W/C_DA = 50$, the altitude of maximum heating is approximately 109,000 ft. At this condition, the missile's velocity is still some 85 per cent of its value outside the Earth's atmosphere. For the velocities necessary for a range of the order of 5000 miles, such altitude and velocity conditions face the designer with heat-transfer rates of very large magnitude although the missile is traveling only some 300 mph when it strikes the ground.

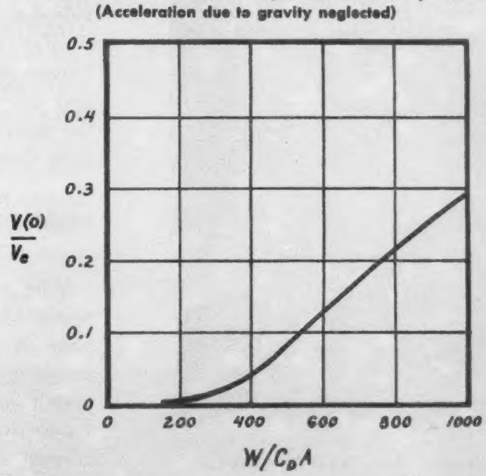
Reducing Heat-Transfer Rates

It was noted by Allen and Eggers that, for a given W/C_DA, the heat transfer can be reduced by making the ratio of viscous drag to total drag as small as possible, since heat transfer to a body depends only on the work done by the viscous forces, and not upon the work done by the total forces acting upon the body. (CONTINUED ON PAGE 108)

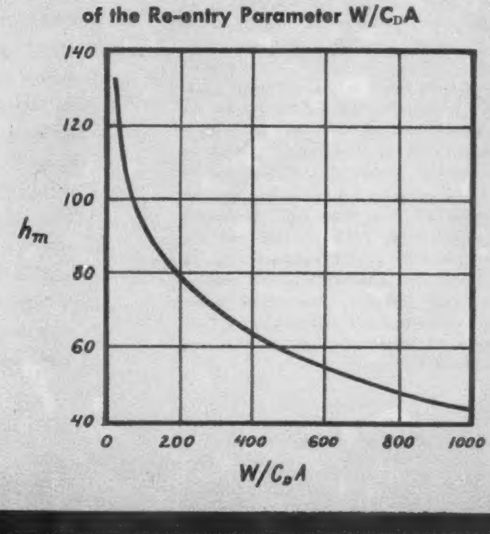


Light emission from the hot gas ahead of a blunt body at high Mach number—in this case, a 90-deg cone-cylinder at Mach 12 xenon.

Ratio of Impact to Entrance Velocities V(O)/V. as a Function of Re-entry Parameter W/C_DA
(Acceleration due to gravity neglected)



Altitude of Maximum Heating h_m as a Function of the Re-entry Parameter W/C_DA

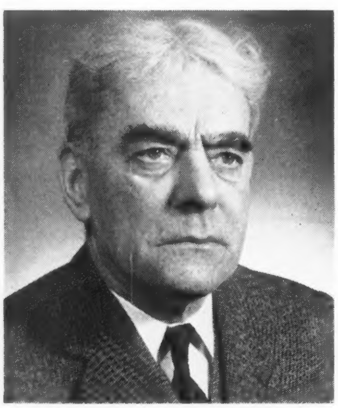


Arc-heated plasma for laboratory hypersonics

Newly developed as a laboratory tool, fluid-stabilized arcs provide a sustained high-energy air stream for the study of materials and thermal-protection schemes in the hypersonic regime

By T. R. Hogness

CHICAGO MIDWAY LABORATORIES, CHICAGO, ILL.



T. R. Hogness is founder (1951) and director of the Chicago Midway Laboratories and a professor of chemistry at the Univ. of Chicago. He was on the chemistry staff of the Univ. of California (where he received a Ph.D. in physical chemistry in 1921) from 1919 to 1930, when he joined the staff of the Univ. of Chicago. He has been there since except for leaves to contribute to the defense effort. During WW II, Dr. Hogness was, at various times, scientific liaison officer to the American Embassy in London, director of the Maryland Research Laboratory for OSS, director of the Manhattan Project Chemistry Div. in Chicago, and a member of the Army's European Theater Operations team. His honors include a President's Certificate of Merit and an Sc.D. from Rockford College.

UNTIL the fairly recent development of means for arc-heating air to give high-energy flows, laboratory research into problems of hypersonic flight was sharply limited by lack of equipment for simulating the flight environment. For aerodynamic and some heat-transfer studies, hypersonic wind tunnels, shock tubes, and arc-driven devices, such as the Hot Shot wind tunnel, provided some valuable data. These facilities, however, could not be adapted for studies of material behavior or thermal protection schemes. Present hypersonic wind tunnels do not reproduce the thermal environment; and shock tubes and similar nonsteady-state devices do not maintain the desired test conditions for a sufficient length of time to determine the effectiveness of a protection scheme.

Flight Conditions We Would Like to Simulate

What, briefly speaking, are the range of flight conditions we would like to simulate? The graph at bottom left on the opposite page shows air stagnation energy as a function of velocity. If we consider velocities in the range of 10,000 to 20,000 fps, energy contents range from 2000 to 10,000 Btu/lb. The accompanying graph shows the associated temperature-pressure relationship for selected energy contents. The temperature range of interest lies between 3000 and 10,000 K, well beyond the range of the melting or sublimation temperature of any solid material.

Thus, it is clear that it is impossible to obtain an air flow of the desired energy content by convective heating. Energy may be transferred to the air by other methods, such as adiabatic compression, strong shocks, or spark discharges; but these methods can be sustained only for very short times. The necessary energy, however, can be transferred directly to the air stream by stabilized electric arcs which can maintain test conditions for minutes at a time.

The concerted attack on re-entry and hypersonic-flight problems thus spurred the development and engineering application of fluid-stabilized arcs for study of the hypersonic flow regime. Our laboratory played an important part in this effort. Parallel or subsequent to our development work, other groups engaged in the development of arc equipment for high-temperature applications. A complete

listing of these would now include over 30 companies and government laboratories.

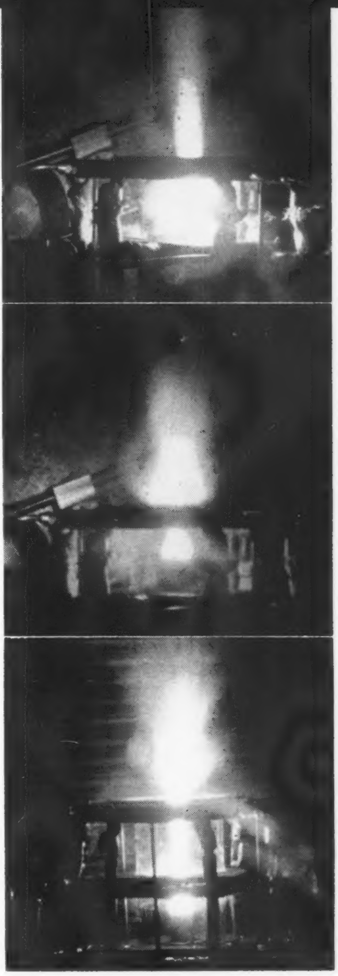
This article briefly reviews our work and outlines the present state of the art.

One of the earliest uses of electric arcs—to raise the temperature of an air stream—dates back to the turn of the century. Air was passed through electric arcs to form oxides of nitrogen for eventual conversion to artificial fertilizer. This process was especially popular in Norway, where some plants utilized as much as 700 kw of hydroelectric power per unit for this purpose. The more economical Haber ammonia process for the fixation of nitrogen supplanted the arc method, and further development of the arc process ceased.

The more recent development of fluid-stabilized arc equipment can be traced to the work of Gerdien and Lotz at Siemens and Lochte-Holtgreven and his associates at the Univ. of Kiel in the 1920's. These studies were carried out to obtain basic information on arc characteristics and a high-intensity light source for basic spectroscopic studies. Both gas- and liquid-stabilized arcs were used by these investigators, who generated plasma temperatures as high as 50,000 K with relatively simple equipment.

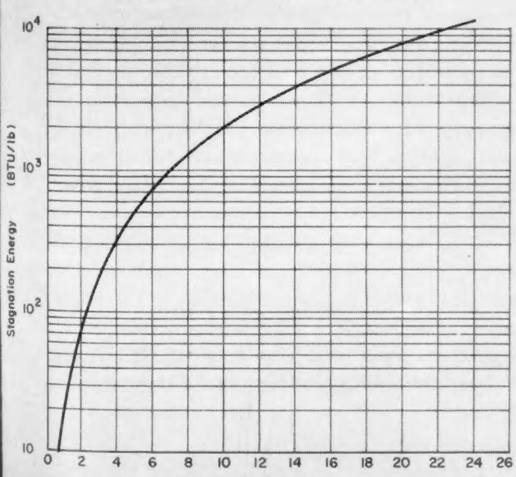
In the summer of 1956, in conjunction with work on the nose cone problem, our laboratory became interested in exploring the potential application of plasma generators to high-energy gas flow. The initial development work was directed toward water-stabilized arcs, utilizing much of the basic data published in the German literature. To enable us to cover reasonably large test sections, units converting upwards of 3000 kw of power in the arc chamber itself were constructed and pressed into operation. Anodes up to 3 in. in diam used for these units gave significant results and valuable operating experience.

To simulate more closely the desired chemical composition, emphasis was shifted toward the development of gas-stabilized arcs in the fall of 1957, under contract with the Air Force. A 1100-kw unit was developed and put into operation in the spring of 1958. This



Three modes of air-arc propagation have been observed: (top) normal high-intensity mode; (middle) low-intensity mode; and (bottom) condensed mode.

Air Stagnation Energy Vs. Velocity



Temperature-Pressure for Three Air Enthalpies (*H*)

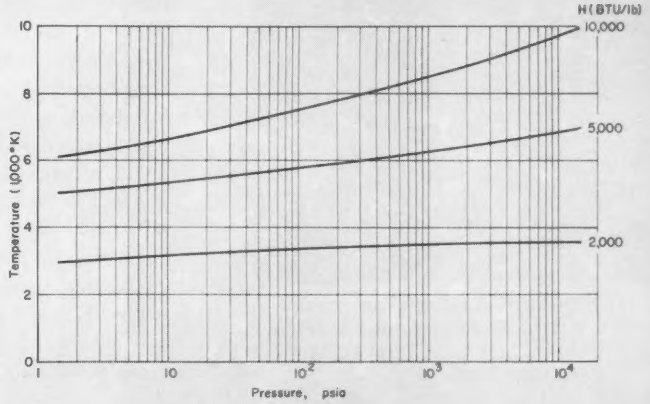
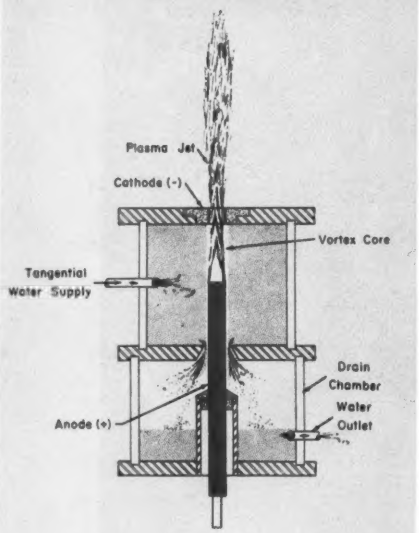
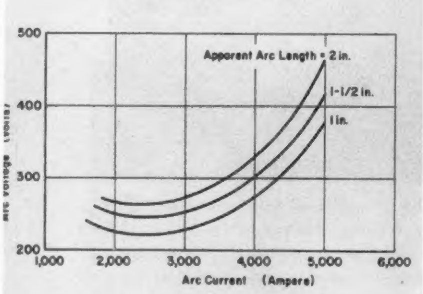


Diagram of Water-Stabilized Arc



Arc Characteristics



Developmental work proceeded to gas-stabilized arcs, such as the one shown here, which has helium as a working fluid.

unit gives energy input into the air stream as high as 9000 Btu/lb for 1 to 2 min.

The basic operating principle of a high-intensity fluid-stabilized arc can best be shown by the water-stabilized arc such as used by Weiss. A diagram of the basic configuration appears at top left. The arc is drawn between a disc-shaped electrode and a centrally located rod-shaped electrode. The arc column is surrounded by a cylindrical wall of water. The disc electrode contains a centrally located orifice, or nozzle. The water column is established by introducing water tangentially with enough energy to form a hollow vortex with almost parallel walls. The vortex diameter is determined primarily by the size of the drain in the lower plate.

The water column and the relatively cold water vapor formed by evaporation restricts the diameter of the ionized gas column and provides a well-defined path for the arc. As the water vapor diffuses into the arc column, it is heated, dissociated, and partially ionized, and is finally discharged through the orifice. The current density and the maximum plasma temperature are increased as the arc column is reduced in diameter.

Design of Gas-Stabilized Equipment

The same principle is employed in the design of gas-stabilized arc equipment. The arc column of hot, partially ionized gas must be surrounded by a well-defined wall of cold gas. This wall is obviously more difficult to achieve with gas-stabilized than with liquid-stabilized equipment, due to the greater mobility of the gas as compared to the liquid phase. In general, it is more difficult to obtain high-current densities in gas-stabilized equipment than in liquid-stabilized devices. The photo at left shows a helium-stabilized arc chamber with the plasma issuing through the orifice. The arc column is rather well defined and steady. Our larger gas-stabilized equipment normally uses air as the working fluid.

The electric power circuitry must be compatible with the electrical characteristics of the arc equipment. Our main power source consists of three rotary synchronous converters capable of delivering a total of 12,000 kw at 600 volts. Since the output voltage is nearly independent of load, a variable resistor is used in series with the arc heater to control arc voltage. Arc current is controlled by varying the distance between electrodes. The desired currents and voltages are maintained by individual electrohydraulic servos; this gives flexibility in operation and permits remote control of the equipment.

The determination of basic arc parameters has until now been outside the scope of our sponsored research work. Some data were obtained in initial calibration runs of a water-cooled unit equipped with Vycor chambers to permit observation of the arc column inside the chamber. Three different modes of arc propagation were encountered, as shown on page 41. The normal high-intensity mode is characterized by a short, confined arc column within the chamber. The low-intensity mode is characterized by a very bushy arc which almost fills the arc chamber. The third mode, which to date has been obtained in only a few cases, has a long, slender, highly compressed arc within the chamber.

The bushy low-intensity arc yields high heat transfer to the chamber walls and causes short chamber life. The high-intensity mode may be regarded as a good example of a convection-stabilized arc; it has good stability and reproducibility. (CONTINUED ON PAGE 47)

Fact sheet on Project Mercury

NASA provides complete rundown on U.S. manned satellite program

Name

Project Mercury is the name given to the manned satellite program of the National Aeronautics and Space Administration.

Project Management

NASA is responsible for the management and technical direction of Project Mercury, with the advice and assistance of ARPA. A NASA Space Task Group, assigned responsibility for a manned space capsule that would orbit the Earth, was set up during the first week of October 1958, under Robert R. Gilruth as project manager. The Group, which reports directly to Abe Silverstein, NASA Director of Space Flight Development, NASA Washington Headquarters, is located at the Langley Research Center, Langley Field, Va.

Objectives

1. To put a manned space capsule into orbital flight around the Earth.
2. To recover successfully the capsule and its occupant.
3. To investigate the capabilities of man in this new environment.

Flight Plan

1. An intercontinental ballistic missile rocket booster will launch the manned capsule into orbit.
2. A nearly circular orbit will be established at an altitude of roughly 100 to 150 statute miles to permit a 24-hr satellite lifetime.
3. Descent from orbit will be initiated by the application of retro-rockets incorporated in the capsule system.
4. Parachutes, incorporated in the capsule system, will be used after the vehicle has been slowed down by aerodynamic drag.
5. Recovery on either land or water will be possible.

Description of Capsule System

1. Vehicle—The manned capsule will have high aerodynamic drag, and will be statically stable over the Mach number range corresponding to flight within the atmosphere. The capsule, of the nonlifting type, will be designed to withstand any known combination of acceleration, heat loads, and aerodynamic forces that might occur during boost or re-entry. It will have an extremely blunt leading face covered with a heat shield.
2. Life Support System—A couch, fitted into the capsule, will safely support the pilot during acceleration. Pressure, temperature, and composition of the atmosphere in the capsule will be maintained within allowable limits for human environment. Food and water will be provided.
3. Attitude Control System—A closed-loop control system, consisting of an attitude sensor with reaction controls, will be incorporated in the capsule. The reaction controls will maintain the vehicle in a specified orbital attitude, and will establish the proper angle for retro-firing, re-entry, or an abort maneuver. The pilot will have the option of manual or automatic control during orbital flight. During manual control; optical displays will permit the pilot to see portions of the Earth and sky. These displays will enable the pilot to position the capsule to the desired orbital attitude.
4. Retrograde System—A system will be provided to supply sufficient impulse to permit atmospheric entry in less than one-half an orbital revolution after application of the retro-rockets. These rockets will be fired upon a signal either initiated by a command link from ground control or by the man himself. The impact area can be predetermined because of this control over the capsule's point of re-entry into the atmosphere.
5. Recovery System—As the capsule re-enters the Earth's atmosphere and slows to a speed approximately that of sound, a drogue parachute will open to stabilize the vehicle. At this time radar chaff will be released to pinpoint the capsule's location. When the velocity of the capsule decreases to a predetermined rate, a landing parachute will open. The parachute will open at an altitude high enough to permit a safe landing on land or water. (The capsule will be buoyant and stable in water.) After landing, recovery aids will include tracking beacons, a high-intensity flashing light system, a two-way voice radio, sofar bombs, and dye markers.
6. Escape Systems—In an emergency situation before orbital altitude is reached, escape systems will separate the capsule from the booster. After the capsule is in orbit, the space pilot can re-enter the atmosphere at any time by activating the retro-rockets. Other safety control features will be incorporated.

Capsule Contractor

McDonnell Aircraft Corp., St. Louis, has been selected by NASA as the source for the design, development, and construction of the space capsule. McDonnell was chosen from a group of 12 companies which submitted proposals in the NASA competition for the capsule. Total cost of the capsule and its subsystems is expected to exceed $15 million.

Guidance and Tracking

Ground-based and booster equipment will guide the capsule into the desired orbit. Ground and capsule equipment will then determine the vehicle's orbital path throughout its flight. The equipment will be used to initiate the vehicle's descent at the proper time and will predict the impact area.

Communications

Provisions will be made for two-way communications between the pilot and ground stations during flight. Equipment will include a two-way voice radio, a receiver for commands from the ground, telemetry equipment for transmission of data from the capsule to ground stations, and a radio tracking beacon. This communications equipment is supplemented by special recovery aids.

Instrumentation

1. Medical instrumentation to evaluate pilot's reaction to space flight.
2. Instrumentation to measure and monitor the internal and external capsule environment, and to make scientific observations.

NOTE: Data will be recorded in flight and telemetered to ground recorders.

Test Program

As in the case of new research aircraft, orbital flight of the manned space capsule will take place only after a logical buildup of vehicle capabilities and scientific data. Project Mercury includes ground testing, development and qualification flight testing, and pilot training.

NASA Administrator T. Keith Glennan (left) discusses space capsule model with J. S. McDonnell, president of McDonnell Aircraft Corp., which will build the Project Mercury capsule.

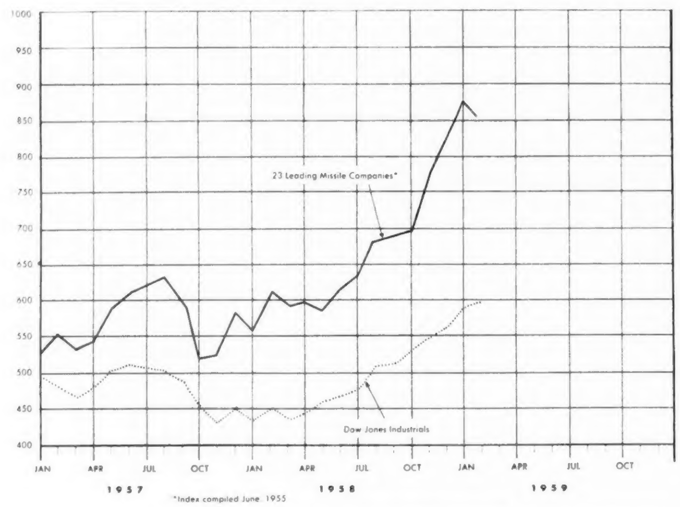
Missile market

BY ROBERT H. KENMORE, Financial Editor

This month's guest columnist is Martin Heilbrunn, ARS Member, security analyst, and member of the Research Dept. of the New York Stock Exchange firm of Bache & Co.

By MARTIN HEILBRUNN
Bache & Co.

THE MARKET AT A GLANCE



	Feb. 1959	Jan. 1959	% Change	Feb. 1958	% Change
Dow-Jones Industrials	594	584	+1.7	450	+32.0
Missile Index	856	881	−2.8	609	+40.6

DURING 1958, and especially during the closing months, prices of electronics stocks catapulted into new high ground, reflecting the high regard of investors for the future of the industry. The aggressive purchase of electronics equities appears to have been overdone. While the outlook for the industry over the long term is favorable, the advanced prices in most instances involve the assumption of an undue amount of risk. In some cases, the price-to-earnings multiples have moved to levels of forty to fifty times 1959 earnings, which may be 10–25 per cent above satisfactory 1958 performances. Caution is becoming a byword.

While the electronics outlook for 1959 continues to be favorable and promises revenues above those of 1958, the situation is different from last year in that the companies are already operating at a high level. The accelerated pace makes some companies vulnerable to contract cancellations or other adverse reports, and year-to-year comparisons are not likely to be as impressive this year.

Also of interest is the fact that the investor is fickle and tends to become tired of an industry group. Several years ago, the elecronics industry was of limited interest to the investor. This could again occur despite growth opportunities, since the prevailing high prices make the group somewhat uninteresting at this time.

Needless to say, there will always be equities which will outperform the industry market-wise. For instance, present prices of Motorola, Bendix Aviation and Eitel-McCullough still reflect disappointing results in 1958. All three companies should do much better this year and their stock appears to be attractive.

Motorola has established an enviable reputation in the consumer product area, producing auto, home, and portable radios, as well as television sets. These products, which are still important to the company's over-all sales picture, have been a base from which to jump into newer and more promising electronics areas.

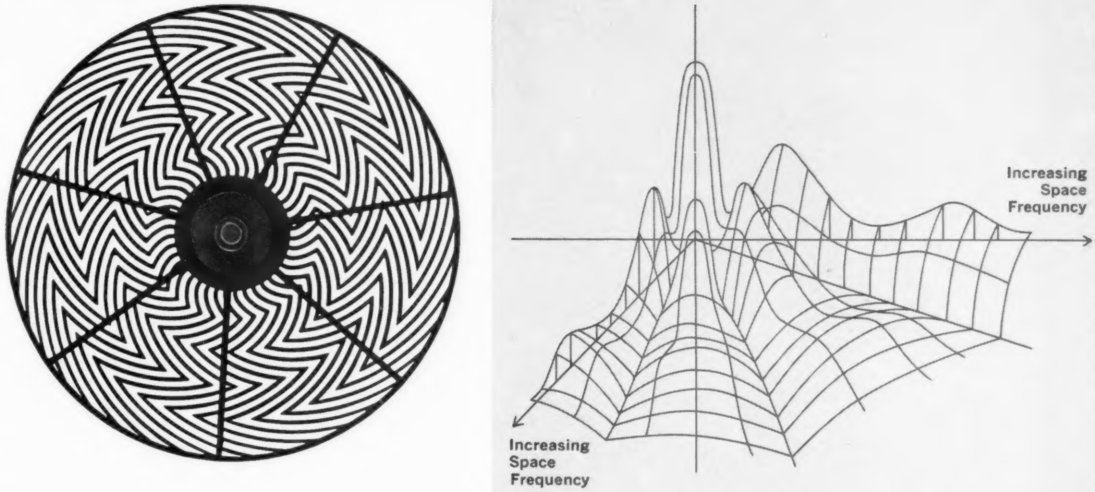
In two-way mobile communications, Motorola is the largest factor, accounting for a larger share of the market than all competitors combined. This product area is growing faster than the electronics industry as a whole and is also more profitable. In addition, Motorola has been very active in the development of a line of semiconductors and is mass-producing transistors. In 1959, its already large production facilities will be doubled. Due to the company's important stake in the radio field, its transistor position is particularly strong with its own competitive market for these devices.

Military electronics also have been significant, accounting for about 20 per cent of sales. With the continued rise in military electronics, particularly for missiles and advanced communication and radar systems, Motorola's position is outstanding in its efforts to obtain additional defense business.

From 1955 to 1957 inclusive, earnings of Motorola, in common with most other manufacturers of consumer electronics items, were adversely affected by intensely competitive conditions. Yet, in each year, net income was in excess of $4 per share. During 1958, Motorola was hard hit by the recession, affecting not only television sets but especially automobile radios, which slumped in the face of lower car sales. These hard-hit areas in turn affected the company's transistor production, geared to a higher level of sales. On top of these difficulties, military operations resulted in sharply reduced earnings. Accordingly, net income for 1958 declined to about $3.50 per share from $4.04 in 1957. In 1959, all phases of the company's activities should improve. Military electronics should show marked earnings gains; sharp recession in consumer durable goods should be reversed; and recovery for both television sets and radios may be pronounced. As a result, earnings should rise to about $5 per share in 1959.

On a long-term basis, Motorola should continue to show substantial growth. The company has one of the most extensive engineering and research organizations in the entire electronics industry. The financial condition of Motorola also is strong

(CONTINUED ON PAGE 90)



Phosphor bronze reticle (actual size) and space frequency transfer characteristics of circular aperture reticle.

TARGET DISCRIMINATION IN INFRARED DETECTION SYSTEMS

The pioneering field of infrared detection offers many challenging opportunities to scientists and engineers at Ramo-Wooldridge for advanced studies in the solution of target discrimination problems. Research is continually under way at Ramo-Wooldridge in the integrating of infrared detection devices with the latest electronic systems techniques for enhanced target detection on the ground and in the air.

The phosphor bronze reticle, or image chopper, illustrated above was developed by Ramo-Wooldridge. It indicates a marked stride in space filtering discrimination concepts, and is used for target signal enhancement in guided missiles, anti-aircraft fire control and air collision warning applications.

The reticle is used in the focal plane of an infrared optical system and is rotated to chop the target image for the desired space filtering. It is also employed in time filtering, such as pulse length discrimination, or pulse bandwidth filtering.

Space filtering is critical to infrared systems, because of its ability to improve the detection of objects located in the midst of background interference. In a manner similar to that used in the modification of electronic waveforms by electrical filtering, space filtering enhances the two-dimensional space characteristics of a target. The size and features of the target are highlighted and the undesired background eliminated.

Scientists and engineers with backgrounds in infrared systems—or any of the other important areas of research and development listed below—are invited to inquire about current opportunities at Ramo-Wooldridge.

- Electronic reconnaissance and countermeasures systems
- Analog and digital computers
- Air navigation and traffic control
- Antisubmarine warfare
- Basic research
- Electronic language translation
- Information processing systems
- Advanced radio and wireline communications
- Missile electronics systems

RAMO-WOOLDRIDGE

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a division of ***Thompson Ramo Wooldridge Inc.***

Arc-Heated Plasma

(CONTINUED FROM PAGE 42)

It is this kind of arc propagation that has been chosen for our work during the past year. The third mode appears to be pinch-stabilized by self-induced magnetic forces. The conditions necessary to obtain the transition from the high-intensity to the pinch-stabilized mode have not yet been fully developed.

Approximate arc voltage and current data have been obtained for the low-intensity (negative slope) and high-intensity (positive slope) modes of operation, as shown in the graph on page 42.

The use of electric arcs for the production of high-energy air flows has provided the engineer and scientist a novel tool for studies in the hypersonic range. The work carried out so far has been predominantly with d.c. arcs, operating at essentially atmospheric pressures. Power inputs have usually been in the 60- to 100-kw range, with a few installations now operating above 1000 kw.

To achieve better aerodynamic simulation, chamber pressures above 400 psia may be necessary, and mass flow rate requirements will probably be in the 1- to 4-lb/sec range, resulting in net energy demands of 10,000 to 40,000 kw. The higher pressure requirements will increase the operating voltage, since arc voltage varies nearly as the square root of the operating pressure. A high-voltage d.c. supply of the required power rating is rather expensive and certainly not readily available. For these high power installations, multiphase a.c. arcs appear very attractive, but very little experience and operating data are available so far.

Another area that requires considerably more study is the shielding, or cooling, problem of tunnel and nozzle walls. Extensive water cooling is employed now. In some instances, 40 to 60 per cent or more of the energy input into the air stream passes into the cooling water before the test section is reached. Unless these losses can be drastically reduced by some thermal-protection scheme, such as magnetic shielding, power sources as large as 100,000 kw may be required.

In conclusion, we see that electric arc heating has opened a new frontier to high-temperature research by providing a reliable source of high-temperature gas.

Suggested Additional Reading

Conference on Extremely High Temperatures, John Wiley & Sons, New York, 1958.

ARS news

Maryland Section Lists Space Institute Speakers

The complete program of the Space Education Institute co-sponsored by the ARS Maryland Section and the Univ. of Maryland has been announced. To be held at the Enoch Pratt Library in Baltimore, the institute will consist of nine lectures, beginning March 2, and is open to ARS members, school teachers, and others who may be interested. The program:

March 2, "Impact of the Space Age on Society," Addison M. Rothrock, NASA; March 9, "From Fire-Arrows to Space Vehicles," George Trimble Jr., The Martin Co.; March 16, "Propelling the Space Vehicle," Kurt Stehling, NASA; March 23, "Living in Space," Col. John P. Stapp; April 13, "Brains and Brawn of Rockets," Grayson Merrill, Fairchild Guided Missiles Div.; April 20, "Educational Requirements for the Space Age," Joseph Rowland, Martin Co.; May 4, "University Research for the Space Age," Martin Summerfield, Princeton Univ., and Editor, ARS Journal; May 11, "Space Stations and Interplanetary Travel," Peter Castruccio, Westinghouse; and May 18, "Role of the Teacher in the Space Age," Glen Baugh, Univ. of Maryland.

Registration fee for the nine lectures is $7.50. The lectures will be given every Monday night from 7:30 to 9:30 p.m.

Abstracts of IAF Congress Papers Due by April 15

Abstracts of papers which prospective authors wish to submit for presentation at the 10th IAF Congress in London Aug. 31–Sept. 5 should be at ARS National Headquarters by April 15. Abstracts will then be transmitted to the appropriate ARS Technical Committee for screening, with the entire procedure coordinated by ARS National Program Chairman Brooks Morris. A quota has been set for American papers at the Congress. Deadline for final manuscripts is May 15.

Standing Committee Chairmen Appointed

Chairmen appointed by Col. John P. Stapp, ARS National President, to head up standing committees of the Society during 1959, are:

Membership, Wernher von Braun; Program, Brooks Morris; Publications, Simon Ramo, with W. H. Pickering as vice-chairman; Policy, Martin Summerfield; Finance, Sam Hoffman; Awards, Krafft Ehricke; and Nominating Committee, George Sutton.

The appointments were approved by the Board at its January meeting in New York.

Thermodynamics Conference Scheduled for May 12-13

Another special subject conference has been added to the ARS calendar for 1959—a Rocket Thermodynamics and Propellant Handling Conference, to be held in Columbus, Ohio, May 12–13. Four sessions have been scheduled to date. These will deal with propellant calculation methods and results, thermodynamic and transport properties, and handling. General chairman of the conference is Alexis W. Lemmon Jr., assistant chief, Chemical Engineering Div., Battelle Memorial Institute, Columbus.

ARS Adds 4593 New Members During 1958

ARS recorded the largest growth in membership in the Society's 28-year history during 1958, adding a total of 4593 individual members during the year. Total membership in the Society now tops the 12,000 mark.

Goddard Rocket Center To Open at Roswell, N.M.

A new rocket center dedicated to Robert H. Goddard will be opened April 25 at Roswell, N. M., where Dr. Goddard performed many of his early rocket experiments. Hugh Milton, assistant secretary of the Army, will be guest of honor at the dedication ceremonies. All ARS members are invited to attend the event, honoring the great U.S. rocket pioneer.

TECHNICAL COMMITTEES

Instrumentation and Control: Herbert Friedman, superintendent of the Atmosphere and Astrophysics Division

of the Naval Research Laboratory, Washington, D.C., has been appointed Chairman of the ARS Instrumentation and Control Committee. Dr. Friedman has been with NRL since 1941, serving as head of the Electron Optics Branch from 1941 to 1958, when he was promoted to his present post. Since 1949, he has been engaged in upper-air rocket research projects, particularly in the field of solar-terrestrial relationships.

Herbert Friedman

Committee members are: Richard C. Deegan, Space Flight & Missiles Div., Bell Aircraft; Fred Klemach, Vickers, Inc.; Frederick F. Liu, Dresser Dynamics; George W. Hoover, ONR; E. N. Bowen, General Motors Research Staff; Theodore K. Steele, Bulova Research & Development Labs; John E. Witherspoon, Rocketdyne; and Charles R. Tallman, Aerojet-General.

Liquid Rocket: Committee Chairman Y. C. Lee of Aerojet-General has announced the addition of eight new members. They are: Kurt Berman, GE Malta Test Station; J. R. Dunn, Space Technology Labs; John R. Youngquist, Martin-Denver; D. C. Schiavone, Bell Aircraft; C. H. King, Pratt & Whitney; A. G. Thatcher, Reaction Motors; and Robert Youngquist and Richard Canright, ARPA.

Nuclear Propulsion: Make-up of the Nuclear Propulsion Committee has been announced by Chairman Stanley V. Gunn, Rover Project Engineer,

Stanley V. Gunn

On the calendar

1959

March 3–5	1959 Western Joint Computer Conference, sponsored by IRE, AIEE, and Assn. for Computing Machinery, Fairmont Hotel, San Francisco.
March 8–11	ASME Gas Turbine Power Conference & Exhibit, Netherlands-Hilton Hotel, Cincinnati, Ohio.
March 9–12	ASME Aviation Div. Conference, Statler-Hilton Hotel, Los Angeles, Calif.
March 11–12	9th Annual Iron and Steel Conference, sponsored by ISA Pittsburgh Section, Pittsburgh.
March 16–20	ASM 11th Western Metal Congress & Exposition, Ambassador Hotel and Pan-Pacific Auditorium, respectively.
March 19–20	Flight Propulsion Meeting, sponsored by IAS, Hotel Carter, Cleveland, Ohio.
March 23–25	**ARS Flight Testing Conference, Daytona Beach, Fla.**
March 31–April 2	Millimeter Waves will be the theme of 9th International Symposium of Polytechnic Institute of Brooklyn (N.Y.) Microwave Research Inst., co-sponsored by AFOSR, Army Signal R&D Lab, ONR, and IRE.
April 5–10	5th Nuclear Congress of Engineers Joint Council, Cleveland Auditorium, Ohio.
April 6–10	40th Annual Convention of the American Welding Society, Chicago.
April 12–19	World Congress of Flight, sponsored by Air Force Assn., Las Vegas, Nev.
April 16–17	Reliability Symposium of the Boston Section, American Society for Quality Control, at Statler-Hilton Hotel, Boston, Mass.
April 22–24	3rd Annual Technical Meeting of the Institute of Environmental Engineers, LaSalle Hotel, Chicago.
April 30–May 1	**ARS Controllable Satellites Conference, MIT, Cambridge, Mass.**
May 4–7	5th ISA National Instrumentation Flight Test Symposium, Seattle, Wash.
May 25–27	**National Telemetering Conference, co-sponsored by ARS, AIEE, IAS, and ISA, Denver, Colo.**
June 8–11	**ARS Semi-Annual Meeting and Astronautical Exposition, San Diego, Calif.**
June 11–13	1959 Heat Transfer and Fluid Mechanics Institute, Univ. of Calif., Los Angeles.
Aug. 9–12	ASME-AICE Heat Transfer Conference, Univ. of Connecticut, Storrs, Conn.
Aug. 24–26	**ARS Gas Dynamics Symposium, Dynamics of Conducting Fluids, Northwestern Univ., Evanston, Ill.**
Aug. 28–29	British Commonwealth Space Flight Symposium, Westminster, London.
Aug. 31–Sept. 2	4th Int'l Symposium on Free Radical Stabilization at National Bureau of Standards, Washington, D.C.
Aug. 31–Sept. 5	**10th Annual International Astronautical Federation Congress, Westminster, London.**
Sept. 22–24	Industrial Nuclear Technology Conference, co-sponsored by Illinois Inst. of Tech., at Morrison Hotel, Chicago.
Sept. 24–25	**ARS Solid Propellants Conference, Princeton Univ., Princeton, N.J.**
Oct. 6–9	Int'l Symposium on High Temperature Technology, sponsored by Stanford Research Institute, at Asilomar, Calif.
Oct. 7–9	ASME-AIME Solid Fuels Conference, Cincinnati, Ohio.
Oct. 12–14	National Electronics Conference, Co-sponsored by Illinois Inst. of Tech., at Hotel Sherman, Chicago.
Oct. 26–30	1959 National Conference of the Society of Photographic Scientists & Engineers, Edgewater Beach Hotel, Chicago.
Oct. 28–29	6th Annual Computer Applications Symposium, sponsored by Illinois Inst. of Tech., at Morrison Hotel, Chicago.
Nov. 16–20	**ARS 14th Annual Meeting and Astronautical Exposition, Washington, D.C.**

Rocketdyne. Committee members are: Col. Jack L. Armstrong, AEC Reactor Development Div.; Raemer Schreiber, Los Alamos Scientific Lab; Gaylord W. Newton, GE Aircraft Nuclear Propulsion Dept.; Chiao J. Wang, Space Technology Labs; Charles H. Trent, Aerojet-General; Theodore C. Merkle, Univ. of California Radiation Lab; Frank Rom, NASA Lewis Research Center; and Alan R. Gruber, Astro Div. of Marquardt Aircraft.

Guidance and Navigation: Makeup of the Committee has been announced by Lawrence S. Brown of Ford Instrument Co. Div. of Sperry Rand, chairman. Walter Wrigley of MIT will serve as vice-chairman. Serving for one year will be Charles J. Mundo of Arma; R. J. Parks of JPL; Robert E. Roberson, Autonetics Div. of North American; and William C. Strang of Convair. All were formerly members of the Instrumentation and Guidance Committee.

Serving for a two-year term are Frank Banta, Navigation Branch, WADC; James S. Farrier, Navigation Branch, ABMA Guidance and Control Labs; Donald P. LeGalley, AC Spark Plug Div. of General Motors; Newell D. Sanders, NASA Asst. Director for Advanced Technology; and Roger S. Warner Jr. of ARPA.

ARS 1959 Paper Deadlines

Date	Meeting	Location	Deadline
March 23–25	Flight Testing Conference	Daytona Beach, Fla.	Past
April 30–May 1	Controllable Satellites Conference	MIT	Past
May 25–27	National Telemetering Conference	Denver, Colo.	March 19
June 8–11	Semi-Annual Meeting	San Diego, Calif.	March 9
Aug. 24–26	Gas Dynamics Symposium	Northwestern Univ.	May 22
Aug. 31–Sept. 5	10th IAF Congress	Westminster, London	May 15
Sept. 24–25	Solid Propellants Conference	Princeton Univ.	June 22
Nov. 16–20	14th Annual Meeting	Washington, D.C.	Aug. 17

Send all papers to Program Chairman, ARS, 500 Fifth Ave., New York, 36, N.Y., or to appropriate committees.

SECTIONS

Alabama: Rodney D. Stewart of Thiokol Chemical Corp. has been elected president of the section for 1959. Vice-president will be Konrad Dannenberg of ABMA.

The annual banquet on Dec. 16 was a great success, drawing a large attendance and a host of important guests. **R. B. Rypinski,** chief engineer for field support, Chrysler Missile Div., was the featured speaker. In his address, he noted that field support, which he referred to as "the care and feeding of missiles," is one aspect of the missile system which does not get enough attention. Maintenance analysis, operational readiness procedures, and technical representatives are the three most important elements in field support, he noted, and account for a good proportion of the cost of the weapon. Simplification of missiles and turning them from complex laboratory instruments into weapons the average high school graduate can handle, are the major tasks now facing experts, he added. His address was illustrated by a film strip on field support and a movie on the development of the Corporal missile.

Columbus: The fourth fall meeting of the section was held at Battelle Memorial Institute on Dec. 9. After a short business session, the speaker was introduced by the Program Chairman, Arthur Greshemer. **T. J. Keating,** chief of rocket propulsion at Wright Air Development Center, spoke on the topic "Requirements for Propulsion of Space Vehicles." He reviewed the various requirements which must be met before a successful flight into space can be made, and discussed the desirability of a system that has a high ratio of combustion-chamber temperature to molecular

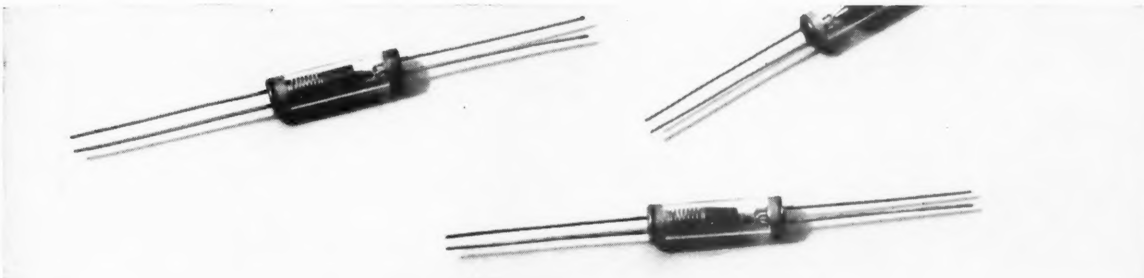
Highlights of Alabama Section Annual Banquet

Alabama board members pose prior to the banquet. Left to right: Cliff Fitton; Conrad Swanson; Konrad Dannenberg, the newly elected vice-president; W. A. Davis; Rod Stewart, 1959 president; Milton D. Anderson; and David H. Newby.

Newly elected president Rod Stewart (left) and outgoing president David H. Newby flank guest speaker R. B. Rypinski of Chrysler Missile Div.

Among the banquet guests were (left to right) Harold W. Ritchey of Thiokol, Lovell Lawrence of Chrysler, and Maj. Gen. John B. Medaris, ABMA.

HUGHES THERMAL RELAYS



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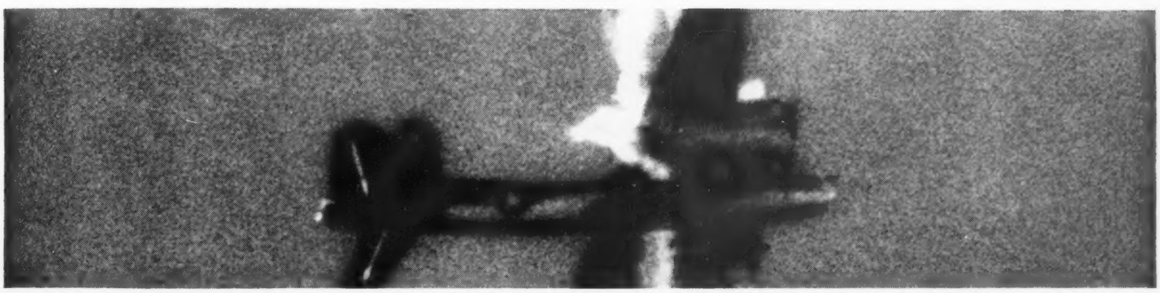


IN GUIDED MISSILES

Hughes now makes commercially available a completely reliable single action switch. Used in the Falcon, field proven as a reliable missile, this Hughes relay is engineered to meet the most exacting of requirements.

With unusual speed of action, firing signal triggers the release of constrained contact...contact closes upon fixed contact point...switch circuit becomes permanently closed.

In a typical application, 3.0 volts DC applied to a firing circuit of 1.2 ohms fire within 0.3 seconds.

For additional information please write: Hughes Products Marketing Department, International Airport Station, Los Angeles 45, California.

SPECIFICATIONS

MECHANICAL—Body Size: Maximum diameter 0.252″; length .920″. Total weight: Less than 0.1 oz.

ELECTRICAL—**Before Firing:** Insulation resistance is greater than 200 megohms. Minimum breakdown voltage 600 volts.

Firing: 2 volts minimum required. Actual voltage dependent upon closing time desired.

After Firing: Circuit resistance less than 0.3 ohm.

ALTITUDE—Any.

OPERATING TEMPERATURE: −55°C to +125°C.

Creating a new world with ELECTRONICS

HUGHES PRODUCTS

SEMICONDUCTOR DEVICES • STORAGE AND MICROWAVE TUBES • CRYSTAL FILTERS
OSCILLOSCOPES • RELAYS • SWITCHES • INDUSTRIAL CONTROL SYSTEMS

At ARS Cleveland-Akron Section Meeting

Left to right, George Shimp, president, ASME, Cleveland Section; Col. John P. Stapp, ARS National President; Paul Ordin, president, and Edward Rapp, Membership Committee Chairman, of the Cleveland-Akron Section, pose at joint ARS-ASME meeting in Cleveland.

weight, subject to structural limitations. Rockets operating with very low pressures in the combustion chamber appear favorable for space use in order to reduce engine weight and pump requirements. Rockets with high chamber pressures, however, are necessary for the booster stages during the initial launch phase. The talk was illustrated with slides. After the formal presentation, a 25-min AF movie entitled "Man in Space" was shown.

—Loren E. Bollinger

Connecticut Valley: Named to head up the section during 1959 are Carl W. Lemmerman, C. W. Lemmerman, Inc., president; William D. Viets, Fuller Brush Co., vice-president; David C. Grant, Associated Engineers, Inc., secretary; and Donald Griffin, Olin Mathieson, treasurer.

Some 75 members, guests attending the dinner meeting at Hartford Jan. 13 enjoyed an hour of cheer beforehand (through the courtesy of Associated Engineers Inc., Fuller Brush Co., Ground Support Inc., C. W. Lemmerman Inc., Veco Engineering Inc., and Olin-Mathieson Chemical Corp.), and later the presentation of incoming officers and a talk on "Ion Propulsion Systems" by George P. Sutton, Hunsaker Professor of Aeronautical Engineering at MIT. This was a busy and pleasant evening. Prof. Sutton's discussion was especially enjoyable, clear, and direct, describing the concept of ion propulsion, its more significant development problems, and its possible area of usefulness.

—Sheldon Dolinger

Dayton: The November meeting was highlighted by a report on the ARS 13th Annual Meeting in New York, delivered by Col. John P. Stapp, newly elected ARS National President.

The section is pushing plans for a Space Age Week to be held in the near future in Dayton.

Launch a Good Year

Outgoing president of Connecticut Valley section Charles H. King Jr. passes on gavel and charter to his successor (right) Carl W. Lemmerman.

Ft. Wayne: F. H. Brady, 1959 president of the section, was the featured speaker at the November meeting. He spoke on the purposes and progress of the U.S. lunar probe and space exploration program, summarizing the first three AF probe shots and also discussing the goals of the Army lunar probe program. In his talk, he described the principal astronomical features of the moon and pointed out the prime areas of scientific investigation at which the lunar program is aiming.

At the December dinner meeting, Robert Pominville, newly elected vice-president, presented the section with two films taken at Cape Canaveral, which showed firings of the principal missiles in the U.S. arsenal, as well as the launchings of the first Army Explorer and Navy Vanguard.

A short ceremony was held immediately after dinner when M. Storlee, past vice-president and newly elected secretary, presented the gavel to the 1959 vice-president, Robert Pominville.

Other newly elected officers attending the dinner were Frank Brady, president, and G. S. Fogel, treasurer

—G. S. Fogel

Kansas City: ARS National President John P. Stapp presented the section with its charter at a meeting on Jan. 20 attended by a number of local industrial, military, and educational leaders. Col. Stapp was the guest speaker at the meeting. Alan R. Pittaway of Midwest Research Institute is president of the section.

Maryland: At the Dec. 2 meeting, president N. Elliott Felt announced that a space education workshop for Maryland teachers will be sponsored by the section in the spring of 1959. The curriculum of this workshop will include nine lectures and discussions. Speakers already scheduled include George Trimble Jr., vice president and general manager of Martin's Space Flight Div., who will discuss space flight; S. Fred Singer, professor of physics at the Univ. of Maryland, who will describe what colleges are doing to prepare for the space age; and Kurt Stehling of NASA, who will speak on rocket propulsion.

Such sessions, designed to acquaint Maryland teachers with the latest advances in the state of the art of rocketry, will be patterned after the pioneer workshops conducted earlier this year by Martin-Denver and the Florida section.

Also at this meeting, an ARS scroll award was presented to previous section president, Samuel Fradin, in recognition of his contributions to local Society activities.

Ceremonies at Fort Wayne

Manley Storlee (second from left) presents gavel to Robert Pominville, newly elected vice-president of the Ft. Wayne Section, as Frank Brady (far left), 1959 president of the section, and program chairman Donald Roberson look on.

The main speaker of the evening was guest **Warren W. Berning,** member of the National Academy of Sciences Special Committee for the IGY, who gave an illuminating talk, illustrated with color slides, on "Some Impressions of Moscow." Among his slides were three color views of replicas of Sputniks I, II, and III taken at the Moscow Industrial Exposition.

—Donald Cox

New Mexico-West Texas: At a recent meeting, these officers were elected for the new year: Lew Byrd, president; Nathan Wagner, vice president; Gust Johnson, secretary; and Leroy Eaton, treasurer.

New York: More than 300 selected New York high school students attended the lecture on "Rocketry in the Space Age" and the ensuing panel consultation put on by the section. Much of the credit for this successful event is due **Charles Marsel** and **Paul Torda** for the work they did in organizing it. Dr. Marsel gave the lecture, which was very well received.

North Texas: Newly elected section officers are John A. Kerr, president; Richard W. Rioux, vice-president; Ronald E. Krape, secretary; and J. B. Haden, treasurer.

Southern Ohio: Col. John P. Stapp, ARS National President, was the featured speaker at a meeting on Jan. 9 co-sponsored jointly by the Southern Ohio Section, the Cincinnati Radiation Society, and American Industrial Hygiene Assn. Col. Stapp's topic was "Man, Time, and Space."

An enthusiastic audience of close to 200 at the meeting heard Col. Stapp state that, in his opinion, man is ready now for space flight, but that he will have to wait from two to four years for the proper vehicles. His address was highlighted by movies of the historic rocket sled ride at 632 mph which gained him the title of "fastest man on Earth" and on weightlessness experiments and the Manhigh balloon flights.

On Jan. 20, the Education Committee, under Guntis Kustevics, sponsored a Space Science and Education Meeting for metropolitan Cincinnati high school science teachers and outstanding students at the GE Evendale plant. The meeting, in the form of a panel discussion, attracted more than 250 teachers and students. Moderator of the panel discussion was **S. N. Suciu** of GE, president of the section. Panel members were **Dean Wandmacher,** Univ. of Cincinnati; **George C. Szego, D. Robinson,** and **William Corliss,** GE; **J. Flint,** Cincinnati Testing Labs; and **A. Presnell,** Andrew and Jergens Co. Exhibits of a GE J-79 engine and rocket hardware also highlighted the meeting.

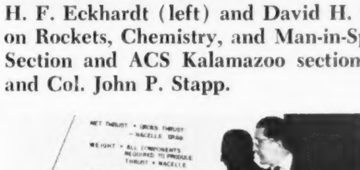
—I. E. Kanter

Southwestern Michigan: The proposed Southwestern Michigan Section, expected to be chartered in the near future, ran a very successful Symposium on Rockets, Chemistry, and Man in Space recently in cooperation with the Kalamazoo Section of the American Chemical Society.

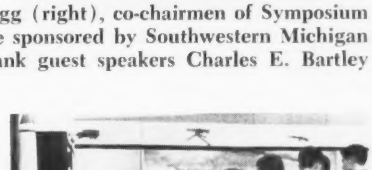
Co-chaired by Hans Eckhardt and David H. Gregg and held at the Western Michigan Univ. student center on Nov. 21, the symposium drew an attendance of about 625 people. Highlights of the event were a full-scale missile exhibit; talks by **Johann G. Tschinkel** of Olin Mathieson (on liquid rockets), **Charles E. Bartley** of Grand Central Rocket Co. (on solid rockets), and **Col. John P. Stapp,** ARS

Spotlighted at S. W. Michigan Rocket Symposium

H. F. Eckhardt (left) and David H. Gregg (right), co-chairmen of Symposium on Rockets, Chemistry, and Man-in-Space sponsored by Southwestern Michigan Section and ACS Kalamazoo section, flank guest speakers Charles E. Bartley and Col. John P. Stapp.



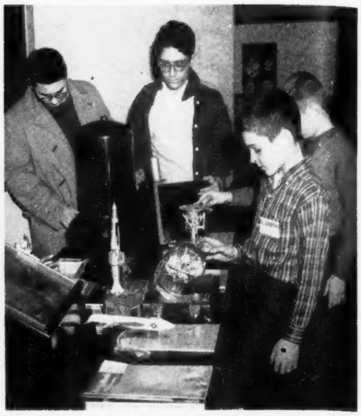
Another guest speaker, Johann Tschinkel, makes a point.



Army missile exhibit drew large crowd of youngsters.

At Southern Ohio Section Space Science Meeting

Panelists for Southern Ohio Section Space Science and Education Meeting were (left to right): George Szego; J. Flint; D. Robinson; S. N. Suciu, section president and moderator; William Corliss; Dean Wandmacher; and A. Presnell.



As always, exhibits of rocket hardware attracted the attention of small fry.

National President; a buffet dinner attended by 250 people; and a panel discussion featuring the three speakers and moderated by Eckardt.

St. Joseph Valley: Some 25 members and guests gathered for the Nov. meeting in the Engineering Auditorium of Notre Dame Univ. to elect new officers and to hear guest **F. A. Heinz**, senior engineer in the ramjet, turbine, and hydraulics group of Bendix Products Div. Missile Section, describe the operation of a typical ramjet fuel-control system. Officers elected for the new year are as follows: R. E. DeFrees, president; B. A. Bishop, vice president; M. S. Ehrenberg, secretary; and L. J. Boler, treasurer.

—**B. A. Bishop**

St. Louis: At the Nov. meeting, held at Washington Univ., members heard guest **William J. Hooper**, professor of physics at the Principia, Elsah, Ill., discuss "Electricity, Magnetism and Gravitation—A New Unified Field Approach." Dr. Hooper's attempts during WW II to develop an airborne ground-speed indicator, based on measurement of the electric field produced by cutting gravitational lines of force, led him to consider in more detail the possible differences in primary and induced electric fields. He described in detail the construction of an experimental apparatus utilizing the interaction of rotating electrical and magnetic fields, and discussed his experimental results, which apparently indicate a reduction in gravitational potential in the vicinity of the rotating fields. It was suggested that the experiments may lead to new interpretation of electric fields and may provide an explanation for the formation of the Earth's gravitational field.

—**Jim Holsen**

Valley Forge Winter Activities

At left, I. M. Levitt, director of the Fels Planetarium and guest speaker at a recent meeting of the Valley Forge Section, chats with members of the section board. Shown, left to right, are V. D. Campbell of Burroughs; Dr. Levitt; section president W. L. Doyle; and A. V. Grosse, president of the Temple Univ. Research Institute. At right, Dr. Grosse explains properties of liquid nitrogen to students who visited the Institute as part of the section's program to interest youngsters in science.

Valley Forge: Members and guests gathered as usual in the auditorium of Conestoga High School in Nov. to hear **I. M. Levitt,** Director, Fels Planetarium and a member of the section's board, talk on "What To Expect on the Moon." Dr. Levitt's discussion was both informative and entertaining.

Through the services of A. V. Grosse, president of Temple Univ. Research Institute and a board member, and William L. Doyle, director of the Institute and section president, local students have been conducted through the facilities of the Temple Research Institute, as part of a program to stimulate their interest in science.

As another part of this program, such ARS corporate members as Burroughs, GE, and Minneapolis-Honeywell have cooperated with the section in setting up science and industry exhibits in Conestoga High School.

—**Kathleen Hoisington**

Wichita: The late **Hans R. Friedrich** of Convair-Astronautics was the guest speaker at the November meeting. His topic was "Man's Place in Space," and, in his address, Dr. Friedrich began by discussing the fundamental laws of celestial mechanics governing the motions of man-made vehicles in space and proceeded onto the energy requirements needed for orbital missions and later, for trips to planets of the inner solar system. Dr. Friedrich also provided a basic schedule for a trip to Mars as an example, and also ran down the design aspects of various types of space vehicles.

STUDENT CHAPTERS

Univ. of Texas: Col. John P. Stapp, ARS National President, presented the

section with its charter at a meeting on Dec. 16 in Austin. **Col. Stapp** also delivered an address on "Man in Space." Instrumental in formation of the chapter were two Chance-Vought employes, Fred Jonah and Ross Jordan, who were present at the charter presentation, along with representatives of the Southwest Research Institute in San Antonio, Thiokol at Marshall, Astrodyne at McGregor, GE at Dallas, and the Univ. of Texas Engineering Faculty.

—**Leroy H. Becker**

CORPORATE MEMBERS

Aerojet-General will market its line of training, research, and test reactors overseas through Westinghouse Electric International sales and service centers. Aerojet also announced that its nucleonics subsidiary will build a test reactor near San Ramon, Calif. The reactor, a pool-type rated at 10 megawatts, will be the first full-scale one known to employ flux peaking. This reactor and associated facilities will be known as the Aerojet Nuclear Test Center. Aerojet-General Nucleonics, the subsidiary, is prime contractor for the AEC's gas-cooled reactor experiment, equipment for which is now under construction at the National Reactor Test Station, Arco, Idaho.

Bell Telephone Labs will sponsor a $1000 annual award for achievement in the field of telecommunications, to be awarded by the American Institute of Electrical Engineers. The award honors Mervin J. Kelley, formerly president and now chairman of the board of Bell Labs, who retires this month.

Burroughs will expand its Tireman Ave. plant in Detroit enough to boost SAGE computer production some 50 per cent. This plant also makes the ground-guidance computer for Atlas. It marks the second major expansion for the Tireman plant in the past four years.

Callery Chemical, which puts its $38 million HiCal plant at Muskogee, Okla., on-stream this spring, will be 50 per cent owned by Gulf Oil Co., which has exercised its option to purchase another 25 per cent of Callery.

Consolidated Electrodynamics approved a plan to incorporate the company's Systems Div. and operate it as a wholly-owned subsidiary. The Systems Div., which produces custom-engineered instrumentation and controls, is located in a recently completed 57,500-sq ft plant in Monrovia, Calif.

Convair Div. of General Dynamics recently began occupying a new $2.5 million facility at Holloman AFB. Sponsored by Convair and the Air Force, the facility will be devoted to armament testing of the Convair Delta Dart all-weather interceptor.

Cornell Aeronautical Lab has extended its wind tunnel facilities to cover tests up to Mach 20. Boeing, McDonnell, and North American have contracted with CAL for testing at hypersonic speeds. CAL is doing transonic wind tunnel testing on a new surveillance drone being developed for the Army Signal Corps by Fairchild Engine and Airplane Corp., and work for several other firms, including Grumman and Martin. CAL and Allison Div. of GM are jointly participating in a $100,000 program of advanced weapon systems studies.

Fairchild Engine and Airplane named its former guided missiles division the Fairchild Astrionics Div., under the general managership of Grayson Merrill.

Ford Instrument, which supplied most of the guidance and control components for Jupiter-C, will be one of 17 companies honored by the Army for contributing to the first U.S. satellite, Explorer I.

GE has assigned some 150 engineers and supporting personnel to Warren AFB to work on the installation and checkout of Atlas guidance equipment.

Grumman Aircraft Engineering will add a $4 million avionics testing and evaluation laboratory to its Long Island plant.

Hercules Powder recently purchased Young Development Labs of Rocky Hill, N.J., which will operate as a division of Hercules.

Hughes Aircraft has named R-O-R Associates Ltd. of Toronto as the exclusive distributor of Hughes commercial products in Canada.

ITT received two U.S. patents covering basic Loran—one on the invention in 1941 by F. G. Bac of the basic principles of hyperbolic radio navigation systems and the other in 1942 by A. Alford for the complete Loran system.

Republic Aviation renamed its guided missiles division the Missiles System Div. This division has R&D projects for anti-ICBM weapons, satellites as weapons, and various missile systems.

Ryan Aeronautical recently opened a military relations office at Huntsville, Ala., to support further its work on target drones and navigational equipment.

Shell Chemical reorganized into five integrated divisions, each to engage in a main line of company business—agricultural chemicals, industrial chemicals, plastics and resins, and synthetic rubber.

Sylvania Electric Products opened its new Reconnaissance Systems Lab at Mountain View, Calif., and commenced work on the associated Electronics Defense Lab. These two laboratories, together with the Microwave Tube Lab and Microphysics Lab, will constitute a major Sylvania division, Mountain View Operations.

Varian Associates of Palo Alto, Calif., and Bomac Labs of Beverly, Mass., will combine operations through an exchange of common stock, with Varian acquiring 80 per cent interest in Bomac. Bomac specializes in a line of switching tubes for pulsed radar.

Westinghouse Electric was cited recently by the Engineers Joint Council for furthering engineering and science through its George Westinghouse Scholarships at Carnegie Tech.. The company gives 10 four-year scholarships to Carnegie each year.

Wyle Labs and Wyle Research Corp., both of El Segundo, Calif., have merged. Wyle Labs has also purchased extensive machine shop and tooling facilities from Mantec Inc. Wyle Associates of El Segundo continues as technical representative for Wyle Labs.

Design and Fabrication

(CONTINUED FROM PAGE 27)

be completely interchangeable from one R/V to another, within certain sequential numbers of units.

3. Optimization of the R/V design would be achieved by optimizing the design of each module, taking into account interaction effects.

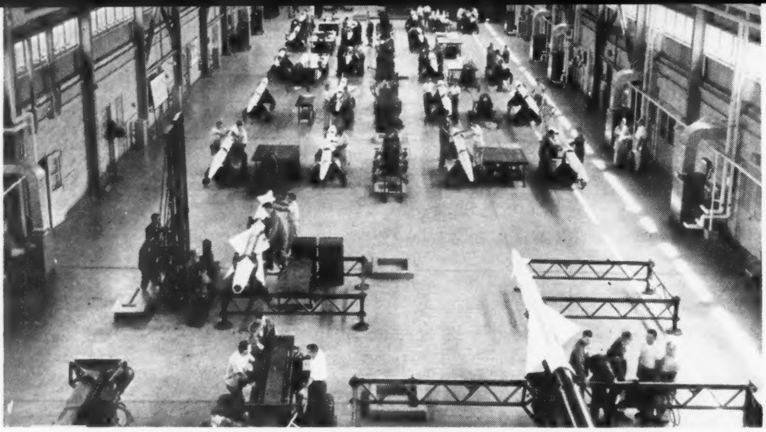
4. Major design changes would be introduced, where required, within the modular concept, and by strict observance of modular interfaces.

5. The structural modules would be such as to serve as convenient subassemblies in the shop.

6. An operational R/V could be achieved at any time in the program by subtraction of R&D components and insertion of the payload.

7. An early, optimized, operational R/V could be achieved, using R&D tooling if necessary, by optimizing each module and declaring it ready for operational use.

This design philosophy stood the test of time remarkably well. It per-



Missile School College grads accepted for the Army Ordnance Guided Missile School, Huntsville, Ala., dissect, reassemble and practice operating controls of Nike-Ajax and Nike-Hercules missiles in school's huge lab. Only three to four per cent of the pupils fail out.

mitted great flexibility operation in manufacturing, acceptance testing, and field operation—including efficient use of subcontractors with particular skills—and facilitated delivery of R&D and operational R/V's on time in an ever-changing program.

With the modular concept well in mind, structural design proceeded. A great many materials and processes were considered before the decision was made to rely basically on the techniques and knowhow developed over the years in the airframe industry. Tried and proved forming techniques, using well-known aircraft alloys, gave a sturdy and dependable structure within the weight limitations. Quality control, inspection, field repair, and change were all simplified considerably by adherence to this course.

Aircraft alloys were confined to a maximum operating temperature around 300 F. Therefore, it was necessary to insulate thoroughly the structure from the heat shield. This was accomplished at a minimum weight penalty. Since the many operating components within the structural shell also had operating temperature limitations, and, in operating, generated heat, the choice of the insulated approach happily resulted in a reduction of the heat-tolerance problem as applied to component design.

Severe dimensional-tolerance conditions prevailed at several points in the structural design. Since each one of the structural modules is, by definition, interchangeable among several vehicles, the normal fit tolerances were those associated with structural airframe access panels, and tooling was designed so as to achieve this interchangeability. The attach points from the R/V to the missile body were held within extremely close limits to insure free separation at the end of powered flight. The concentricity requirements for basic structural rings, to insure weight, CG, and inertial consistency within the specified limits were found to be more severe than those normally associated with good sheet-metal practices. Special tooling and assembly practices were employed to achieve the required precision. Finally, waviness tolerances on certain portions of the substructure required special attention during skin forming and assembly.

Despite these problems, R/V structural forming techniques were kept closely allied to those in use in the airframe industry, with special tooling practices restricted to a few critical areas.

Heat Sink Development

Development of the heat sink presented major problems in design and manufacture. Selection of the basic material was made after careful consideration of technical requirements, weight, and material availability. Many different methods of fabrication were explored, among them welding, casting, spinning, and forging. Full-scale samples were completed by several of these methods before final selection was made. An intensive manufacturing research program was conducted in the area of finishing the external surface to a very fine RMS value over a large surface area. Large boring mills, as shown on page 27, were adapted for basic machining. Automatic surface buffing was developed during the program to insure a uniform finish of high quality. Extraordinary care was exercised to assure that the aerodynamic surface, once established, would not be seriously damaged in handling before flight.

The structural modules support the many varied pieces of equipment which are the building blocks of the various subsystems. The packaging density of the over-all R/V can be compared with that of the electronics bay of a contemporary fighter aircraft or modern jet engine. To achieve this degree of density, maintaining the flexibility required by the R&D portion of the program, while at the same time maintaining weight, CG, and inertia values within close limits, required a high level of weight control. Radial offset of the CG of the assembled R/V, for example, had to be held within a small fraction of an inch. Pitch, yaw, and roll moments of inertia had to be held within a small variation envelope. Moreover, permissible variation of these parameters relative to each other had to be small to prevent certain types of instability. Unique methods of computing, controlling, and measuring the above parameters were derived, and kept weight variations among completed R&D R/V's, as measured after final assembly, consistently within 0.5 per cent of the total weight.

As the ballistic missile program has evolved, new and more exacting requirements for efficient structural design have evolved with it. The payoff for reduction in the ratio of R/V structural weight to payload weight is obviously increased range or greater payload at the same range. Many advanced design concepts are now being employed. The nose cone shown on page 27 suggests the more sophisticated solution to re-entry heating now being attained in the program.

In the structural design area, much attention has been given to the use of composite structural/heat protection materials. The use of structural sandwiches and of light-alloy, close-tolerance castings is being considered for advanced versions of R/V's. Structural testing methods which include the proper simulation of the heat pulse in conjunction with inertial and aerodynamic loading are now in advanced stages of development.

Complete integration of payload and R/V into a common design with no redundancy will reduce structural weight ratios to a minimum. Working toward this goal has required a diligent effort in structural and heat-protection research, and a continuing, vigorous R&D program.

It is heartening to realize that the design lessons of the ballistic missile program are directly applicable to the broad problem of returning man from space.

Re-entry Heat Transfer

(CONTINUED FROM PAGE 23)

face material. Evidently the situation is so complicated that, for practical purposes, some simplifying approximations are essential for progress toward a solution of the problem.

Provided that no light component such as helium or hydrogen is present, the multicomponent gas mixture may usually be replaced by an effective binary mixture (so far as diffusion is concerned). The value of the mass diffusivity (D_{12}) of this binary mixture is not much different from the value of the thermal diffusivity (κ, equal to ratio of heat conduction coefficient to product of gas density and average specific heat, or $k/\rho c_p$). If the ratio of mass and thermal diffusivities were unity, then the transport rate ($\dot{q}$) of heat energy across streamlines would equal minus the ratio k/c_p times the derivative, dh/dy, where h is the complete static enthalpy, which includes both thermal and chemical enthalpies, and y is the distance normal to the surface. *This relationship would hold independently of the mechanism of heat transfer or the magnitudes of the chemical reaction rates.*

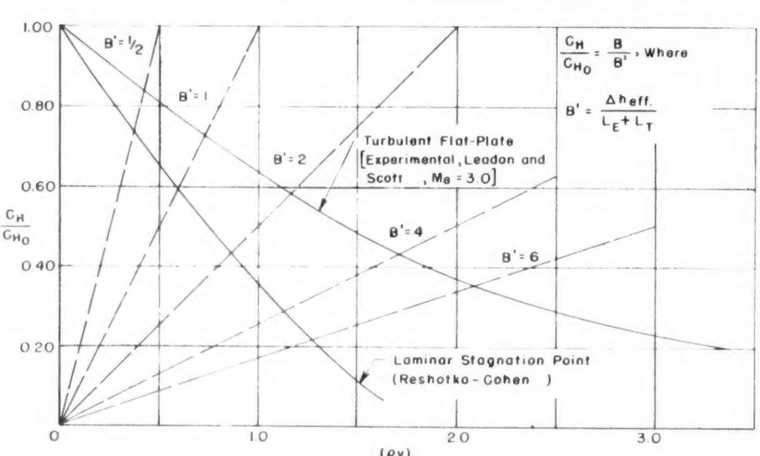
Thus the surface heat-transfer rate depends principally on the total enthalpy difference across the boundry layer. By means of the approximation $D_{12}/\kappa = 1$, the problem is reduced to the same *form* as the low-speed heat-transfer problem. In doing the work, the proper high-temperature gas properties must, of course, be employed.

For spacecraft, the Reynolds numbers are low enough over the critical portion of the entry trajectory to insure completely laminar boundary layer flow. For ballistic missiles, however, transition to turbulent flow is an important phenomenon. If the mechanism of turbulent shear flow is not much affected by enthalpy level, the turbulent heat-transfer rate should also depend mainly on the total enthalpy difference across the boundary layer. The effect of high temperatures appears mainly in the physical properties, and the values of these properties at the outer edge of the gas boundary layer seem to be the most significant for the hypersonic heat transfer problem.

Heat Transfer by Radiation

As indicated in the illustration on page 23, heat energy is transported to the body surface not only by conduction and diffusion across the boundary layer but also by radiation from the hot gas in the shock layer. Fortuntely, it turns out that the emissivity of "air" in equilibrium at temperatures of the order of 8000 to 10,000 K is only a small fraction of 1 per cent, provided the gas density in the shock layer is less than 10 per cent of sea level density. Except possibly for certain purely radiation-cooled designs, the gas radiative heat-transfer rate is always much smaller than the convective or aerodynamic heat-transfer rate.

Mass-Addition Effect on Heat-Transfer Rate (Air—Air)



NOTE: C_H and C_{H_0} are heat transfer coefficients with and without mass addition, respectively. In the expression for the mass-addition parameter, B, ρ is gas density and u and v are gas velocity parallel and normal, respectively, to the body surface. Subscripts are defined in the table of equations on page 23.

At the forward stagnation point of blunt-nosed body of revolution, such as a nonablating solid-heat-sink nose cone, the laminar boundary layer thickness is proportional to the square root of kinematic viscosity (ν) times nose radius (R_0) divided by flight velocity. With the simplifying approximation that the ratio of binary diffusion coefficient to kinematic viscosity (D_{12}/ν) equals unity, the surface heat-transfer rate for a nonablating surface becomes proportional to $k\Delta h/\delta$, where k is the heat-conduction coefficient and δ is boundary layer thickness. More precisely, we have Equation 1. In this equation, surface heat transfer ($\dot{q}_w$) is expressed in Btu/ft^2 per sec; nose radius in feet; and gas density in slugs per cu ft. The constant, 21.3, is very nearly the same for Earth, Mars, and Venus.

For example, at a flight velocity of 23,000 fps, surface heat transfer for a nose radius of 4 ft is about 20 Btu/ft^2 per sec at an altitude of 300,000 ft above the Earth's surface; about 800 Btu/ft^2 per sec at an altitude of 100,000 ft; and about 2070 Btu/ft^2 at 60,000 ft.

In ballistic missile re-entry, the flight path angle remains practically constant in the critical heat-transfer region provided that re-entry angle is greater than approximately 10 deg. Atmospheric drag is much larger than the vehicle weight, and drag coefficient (C_D) is nearly constant. With these approximations, H. J. Allen and A. J. Eggers of Ames Research Center derived Equation 2 for an exponential atmosphere. In Equation 2, Δ equals that ratio of vehicle gross weight to the product of drag coefficient and maximum vehicle cross-sectional area, or W/C_DA; ρ_0 is an atmospheric constant equal to 0.0032 slugs per cu ft; g is the acceleration of gravity at Earth's surface; θ is the angle between flight path and local horizon; and β is an atmospheric constant equal to 1/23,000 ft.

From Equations 1 and 2, we can write Equation 3. The value of surface heat transfer reaches a maximum during re-entry when V/V_E equals 0.87, independently of Δ, so that we arrive at Equation 4. For a hemispherical nose, then, the average heat-transfer rate is about half of the stagnation-point value, and the total heat energy transferred (Q) to the nose during re-entry is given by Equation 5.

In other words, the total heat energy transferred to the surface is a smaller fraction of the initial kinetic energy ($^1/_2 W/gV^2_E$) if the deceleration is carried out at a lower altitude (higher Δ), but the heat-transfer rate is higher.

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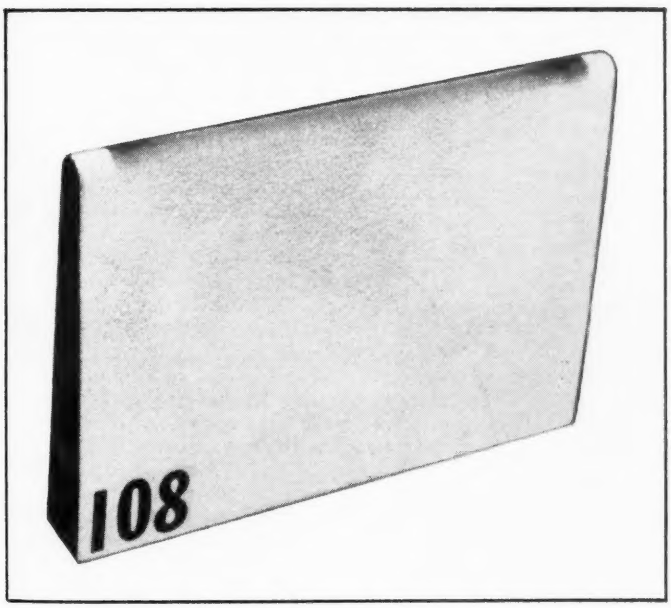

Dramatic proof of vital protection. Photos show two base metal specimens after testing by the Cornell Aeronautical Laboratory, Buffalo, N. Y. Both specimens were subjected to an extremely hot rocket exhaust. No. 109 was uncoated. During a 19-second test it began melting, then burned violently at the rocket exhaust of 3600°F. No. 108 was coated with ROKIDE ceramic coating. After 20 seconds in the exhaust, which reached 4400°F, this protected metal was completely intact and serviceable, showing only the slightest evidence of the flaming exhaust.

Tests by Cornell Aeronautical Laboratory at Army's Redstone Arsenal prove value of another Norton "space age" development

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during re-entry in a manner similar to that of a rectangular slab of thickness, d, as depicted by the graph on page 22. Along the linear portion of the curve of heat transfer ($\dot{q}_w$) vs. slab thickness, the material acts like a "capacitor." On the other hand, the flat portion of the curve at higher $\dot{q}_w$ shows the increasingly inefficient use of the slab material imposed by the requirement that a certain temperature must not be exceeded. The deterioration in performance with increasing W/C_pA or increasing $\dot{q}_w$ is illustrated in the graph on page 21. These considerations, and the requirement that the coolant system be less sensitive to such factors as laminar-turbulent transition, led to the development of the ablating heat sink for ballistic missile re-entry.

Ablation Process

Ablation is the process of absorbing heat energy by removal of surface material, either by melting and possibly subsequent vaporization, or by sublimation. An ablating material possesses higher heat absorptive capacity than a nonmelting solid heat sink not only because the heat of fusion and/or heat of vaporization of the substance is utilized, but also because the material is generally "worked" to a higher temperature. Its internal heat capacity is therefore larger. In some cases, infrared radiation from the gas-liquid interface or the surface of an ablating material also plays an important part in increasing its "effective" heat capacity. But the most spectacular increase in heat capacity is produced when vaporization or sublimation occurs, because the counter-current of relatively "cool" gas away from the surface absorbs heat energy near the surface, distorts the enthalpy distribution, and thickens the boundary layer. This "blockage" of heat transfer by mass addition is illustrated in the figure on page 60.

Gaseous material entering the boundary layer may dissociate, or it may react chemically with the "external" species such as oxygen and nitrogen. When the approximation $D_{12}/\kappa = 1$ is employed, the effect of such chemical reactions appears mainly as an added driving enthalpy potential for heat transfer.

For example, if the combustion of vaporizing or subliming material is oxygen = limited, so that all the oxygen near the surface is consumed, the net rate of heat transfer ($\dot{q}_s$) to molten liquid film (or solid interior) can be defined by Equation 6. In this equation, u and v are gas velocities parallel and normal, respectively, to body surface. The term ΔQ_{EO} is the heat of reaction of the surface material per unit mass of oxygen. The symbol L represents either the heat of sublimation (L_E) or the heat of vaporization (L_{vap}). The first two terms in the expression for Δh correspond to the case of a nonreacting surface, while the term $\rho_e u_e C_H (K_O)_e \; \Delta Q_{EO}$ is exactly the rate of energy transfer that would occur if all the oxygen atoms at the outer edge of the boundary layer that could possibly diffuse to the surface combined with the surface material.

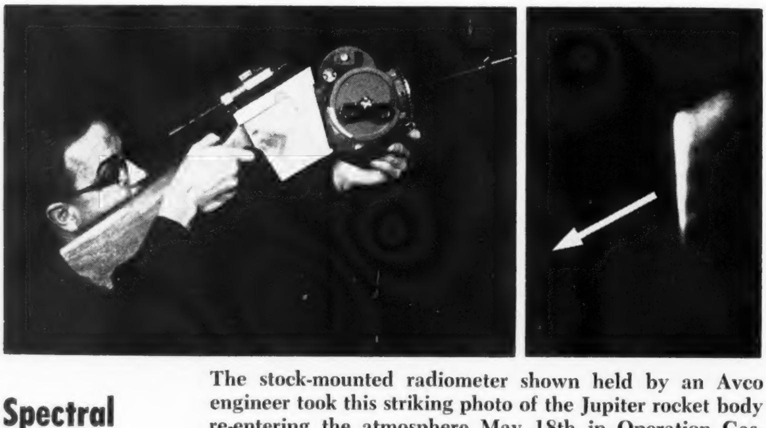
If the dissociation occurs at the surface or at the gas-liquid interface, the heat of dissociation adds to the heat of sublimation or vaporization. If dissociation occurs within the boundary layer, it has no effect on the surface heat-transfer rate, provided again that $D_{12}/\kappa = 1$. Dissociation within the boundary layer merely rearranges the internal distribution of temperature and mass concentration, but not the enthalpy distribution. Thus, we see that exothermic chemical reactions reduce the beneficial effect of mass transfer to some extent, but that endothermic dissociative reactions occurring at the surface enhance this effect.

Subliming Material

When the temperature at the gas-liquid interface of a melting-vaporizing substance is close to the boiling temperature, practically all of the molten liquid vaporizes and $\dot{q}_s = \dot{q}_i = \dot{m}_i H_0$, where $\dot{m}_i$ is the rate of mass addition and H_0 is the heat capacity of the liquid-solid system up to the boiling temperature. For a subliming material, surface heat transfer equals $\dot{m}L_T$, where L_T is the thermal capacity of the solid material up to the surface temperature. From Equation 6, and referring to the graph on page 60, we see that $B' = \dot{m}/\rho_e u_e C_H = \Delta h/L_{vap} + H_0$, or $\Delta h/L_E + L_T$, for a subliming material. (Radiation is readily included in this analysis.) But $C_H/C_{H_0} = B/B'$, and every constant value of B' defines a straight-line relation between C_H/C_{H_0} and B, shown as the dashed lines in the graph. The intersection of the line B' = const. with the curve of C_H/C_{H_0} vs. B gives the normalized rate of mass loss: $(\rho v)_w/\rho_e u_e = \dot{m} \;/\rho_e u_e$. Thus we recognize the "self-regulating" character of gaseous ablation. As Δh increases, $\dot{q}$ increases, and the rate of evolution of gas increases, but this increased mass addition acts to "block" the heat transfer from reaching the solid interior. In other words, B increases much more slowly than B', and is nearly independent of B' for large values of B'.

The reduction in heat-transfer coefficient produced by mass transfer amounts to a substantial increase in effective heat capacity; for example, if $(L_E + L_T)$ or $L_{vap} + H_0) = 1000$ Btu/lb, the effective heat capacity of the ablating material is about 5000 Btu/lb for laminar flow at the stagnation point when $B' = 6$, and about 2000 Btu/lb for turbulent flow. Moreover, the ablating material can cope with the highest heat-transfer rates experienced in re-entry.

Although interest in ablation was stimulated originally by the problems of ballistic missile re-entry, the development of ablating materials has important implications also for the entry of manned vehicles into a planetary atmosphere. As Dr. Solomon points out in his paper, when a nonlifting



Spectral Photo of Juptier

The stock-mounted radiometer shown held by an Avco engineer took this striking photo of the Jupiter rocket body re-entering the atmosphere May 18th in Operation Gaslight, an Army program for studying the physics of re-entry. Avco, sponsored by AF, also made quantitative measurements of intensity of light from re-entry bodies at eight significant wavelengths and covered the scene with 16-mm moving-picture cameras with color film.

vehicle returns to Earth from a lunar or interplanetary mission, the guidance and terminal control system must hold the local entry angle between the limits of about 5 and 6 deg at 400,000 ft altitude. These limits correspond to an "entry corridor" of the order of 10 miles in width. A. J. Eggers, D. R. Chapman and others have studied the process of drag braking by means of successive passes through the Earth's atmosphere, in order to limit peak deceleration and reduce the velocity and eccentricity of the orbit to near-circular conditions. But the guidance and control problem is still very difficult. The purely drag-decelerated vehicle is restricted to a shallow penetration of the atmosphere, and this restriction, in turn, dictates a radiation-cooled design.

Removing Restrictions

These restrictions can be removed by the combined employment of aerodynamic lift and ablating materials. F. W. Hartwig, C. B. Cohen, and the author have shown that if the maximum deceleration is held to 10 g, the maximum allowable entry angle is increased to 10.5 deg for a properly programmed positive lift up to peak g, with a maximum lift–drag ratio of 2.0. Beyond peak g, only modest values of *negative* lift are required to prevent the vehicle from skipping out of the Earth's atmosphere.

At first this may seem surprising; but we observe that lift must provide a counteracting normal acceleration of 1 g *at most*, as compared with longitudinal decelerations of the order of 5 to 10 g. Therefore, the ratio of negative lift coefficient to drag coefficient ($-C_L/C_D$) becomes 0.1 to 0.2. By employing negative lift initially, the minimum value of the local entry angle at 400,000 ft altitude is reduced to about 4.5 deg.

Thus the difficult guidance and control problem is greatly alleviated, and the necessity for multiple-pass drag braking is eliminated. Total heat energy transferred to a vehicle with $W/C_DA = 100$, $\theta_E = 10.5$ deg, and $(C_L/C_D)_{max} = 2.0$ about 40,000 Btu/ft^2/$\sqrt{R_0}$ and the maximum stagnation point heat rate is about 800 Btu/ft^2 per sec/$\sqrt{R_0}$ where R_0 is nose radius.

These values lie well within the capacity of ablating materials. This problem provides strong incentive for developing moderate-temperature ablators of low thermal conductivity to keep insulation weight to a minimum. Clearly, such materials have important applications in many other technical problems involving high rates of energy transfer.

Bullpup Close-Up

Navy men load a Bullpup onto the wing of a FY Fury jet prior to tests of the air-to-surface missile at the Naval Air Missile Test Center, Point Mugu, Calif.

Dynamic Stability

(CONTINUED FROM PAGE 33)

namely, to help determine what magnitude of damping is necessary in order to keep the oscillations convergent over the trajectory. With y representing altitude, the oscillation will be convergent at any altitude at which $\alpha'_{env.}(y) > 0$. This is ensured provided K is of such magnitude that $-Ku'(y)/u(y) > -\frac{1}{4}q'(y)/q(y) > 0$, where the primes denote differentiation.

Missile vs. Manned Vehicle

We can use these two formulas to examine the oscillatory behavior of ballistic missiles and manned re-entry vehicles. Since the oscillatory behavior is so strongly dependent on dynamic pressure, however, let's first see how the dynamic pressure histories differ for the two types of vehicle.

One of the principal differences between a ballistic missile and a manned vehicle is that, to insure the man's survival, the latter cannot be permitted to develop the very large decelerations characteristic of ballistic missiles. A long-range ballistic missile can develop on the order of 60 g in its final descent through the atmosphere. Centrifuge tests suggest that men can safely withstand something on the order of 10–12 g for short periods of time.

Two approaches have been studied that appear to be effective in reducing the decelerations of re-entry vehicles to limits within human tolerance—re-entry trajectories starting from very shallow entry angles, and the use of small amounts of lift. Both approaches have the effect of significantly reducing the magnitude of dynamic pressure experienced by manned vehicles, as can be seen from the first two graphs on page 33.

That is, the ballistic missile enters the atmosphere at a relatively steep angle and descends deep into the atmosphere before it begins to lose speed. In contrast, the manned nonlifting vehicle, entering at a shallow angle, stays at high altitudes for a long time and loses its speed gradually at those altitudes. The manned lifting vehicle stays at high altitudes for an even longer time, and hence loses even more of its speed at high altitudes. The result is that the manned vehicle attains its maximum value of dynamic pressure at higher altitudes than does the ballistic missile. And, since both the air density and their velocities are smaller at those altitudes, the maximum values of dynamic pressure (q) developed by the manned vehicle are significantly smaller than that of the ballistic missile.

Now consider the effect these differing dynamic-pressure histories have on the oscillatory histories, referring to the inequality that has been given involving K. Since the expression's sign determines whether a vehicle's oscillations are convergent or divergent, making the expression equal zero provides a set of circumstances signifying a change from convergent to divergent oscillations, or vice versa. At each point on the known trajectory, one can then solve for the value of K that makes the expression zero. The locus of these values of K plotted against altitude therefore forms a boundary which separates the range of altitudes over which oscillatory divergence is and is not possible.

Such plots are shown for the ballistic missile and lifting and nonlifting manned vehicles in the third graph on page 33. Observe that the curve for each vehicle crosses the $K = 0$ axis twice and that the crossing points correspond to the altitudes at which the dynamic pressure is maximum and minimum. This is also clear from our formula; for, when K is zero, the expression is zero when $q'(y)$ is also zero—that is, when q is maximum or minimum.

Significance

The significance of the figure is this. Vehicles whose K and altitude values fall within the boundaries of their respective curves will experience divergent oscillations over the altitude range within the boundaries. For vehicles whose damping is zero ($K = 0$), divergent oscillations occur in the altitude range from maximum to minimum q.

The main point that becomes evident from inspection of the third graph is that the consequences of a deficiency of aerodynamic damping ($K > 0$) can be more serious for manned vehicles than for ballistic missiles. That is, installation of a device for controlling the oscillatory divergence of vehicles having insufficient aerodynamic damping may be more urgently required for manned vehicles than for ballistic missiles. On the other hand, a compensating factor exists which may ease the problem of controlling oscillatory divergence of the manned vehicle. This is the fact that the dynamic pressure experienced by such a vehicle will be much less than that experienced by the ballistic missile. Since the oscillatory aerodynamic forces are directly proportional to dynamic pressure, the manned vehicle's controlling device will work against forces and frequencies very much smaller than those of the ballistic missile.

Obviously, there are many other dynamics problems which must be solved to ensure the successful completion of a vehicle's mission. Of these, we might mention two prominent ones: First, the possibility of interactions and resonances between the longitudinal motions considered here and lateral motions caused by spinning or rolling; and, second, the effects of aerodynamic forces which can change character or can become highly nonlinear, especially as the vehicle slows down to transonic and subsonic speeds.

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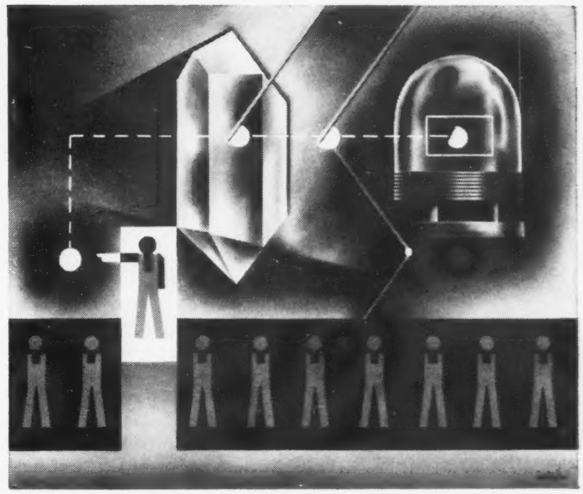

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AIRCRAFT INSTRUMENTS Bulova's new Servo Altimeter combines unsurpassed sensitivity and accuracy with direct-reading tape presentation. Special pressure devices created by Bulova include transducers for air data computers... remote pressure sensors for weather stations and airports... climb and dive indicators... and autopilot altitude controls.

People in the news

APPOINTMENTS

Herbert Friedman, former head of the Electron Optics Branch, Naval Research Laboratory, has been appointed superintendent of the NRL Atmosphere and Astrophysics Div.

Lt. Gen. James H. Doolittle (USAF-Ret.) has officially assumed the office of board chairman of Space Technology Labs. **Edward B. Doll** and **George E. Mueller** have been elected vice-presidents of STL. Doll will serve as associate director of the Systems Engineering Div. and continue in his present position as program director for the AF Atlas, while Mueller will continue on as director of the Electronics Lab. **Robert R. Bennett,** former associate director of the Electronics Lab, has been appointed program director for the Minuteman ICBM system.

H. L. Thackwell, senior vice-president of Grand Central Rocket Co., and ARS Fellow Member, has been assigned to organize and develop a new Space Propulsion Div. for the company.

Hans Wolfhard, former Bureau of Mines research scientist, has joined the Thiokol Reaction Motors Div. research staff as manager of the Physics Dept.

William L. Davidson has been appointed technical coordinator of Food Machinery and Chemical Corp.'s rocket propellant activities. He had been in charge of FMC's Central Chemical Research and Special Projects Labs.

Allen E. Puckett, has been upped from director of operations and associate director to vice-president and director of Hughes Aircraft's systems development lab. He succeeds **Nathan I. Hall,** who becomes vice-president, engineering, succeeding **Robert J. Shank,** named to the new position of vice-president, systems management. **Robert D. Teasdale** joins Hughes from Melpar, Inc., as assistant head of the Systems Analysis Dept., Group Systems Group.

NASA has named the following staff members to its new Inventions and Contributions Board: **Robert E. Littell,** assistant to the director of aeronautical and space research, as chairman; **Paul G. Dembling,** assistant general counsel; **Allen Crocker,** chief of guidance and control programs; **Elliott Mitchell,** chief of rocket booster development programs; **C. Guy Ferguson,** Office of Director of Personnel; and **James A. Hootman** full-time secretary. Other NASA appointments are **Ernest W. Brackett,** as director of procurement and contracting, and **Henry E. Billingsley,** director of the Office of International Cooperation.

Robert M. Groo has been appointed head of Aerojet-General's Florida Field Operations for the Titan project at Cape Canaveral.

Brig. Gen. Harley S. Jones (USAF-Ret.) has been named executive vice-president of Republic Aviation.

Derek F. Lawden, head of the Mathematics Dept., Canterbury Univ. College, Christchurch, New Zealand, has been retained as consultant by the aerophysics branch of the systems engineering directorate in Boeing's Systems Management Office.

Named to serve on the new Pacific Missile Range Industrial Advisory Board are **Grayson Merrill,** general manager of Fairchild Engine and Airplane Corp. Astrionics Div.; **Willy Fiedler,** director of Systems Engineering, Lockheed Aircraft Corp.; **Royal Weller,** Stromberg-Carlson Co.; **W. R. Brode,** science adviser, State Dept.; **Capt. W. S. Diehl,** (USN-Ret.), consulting engineer, Washington, D.C.; **William L. Everett,** dean, School of Engineering, Univ. of Illinois; **L. E. Grinter,** dean, Graduate School of Engineering, Univ. of Florida; **C. C. Lauritsen,** CalTech; **Fred C. Lindvall,** chairman, Div. of Engineering, CalTech; and **William B. McLean,** Technical Director, NOTS, China Lake, Calif.

Stanley I. Kramer, former deputy chief of the Sub-Systems Projects Div., Fairchild Astrionics Div., has been named chief of the Electronics Div., Research Dept.

Ernest Leist of Aerojet-General has been appointed senior field engineer, Polaris missile field activities, Patrick AFB.

W. B. Moen, assistant director of metallurgical research, Air Reduction Research Labs, has been named engineering manager for the newly formed Special Products Dept. **Albert Muller,** assistant to the president, has been appointed vice-president of Air Reduction Sales Div.

Ernst H. Krause, vice-president of Aeronutronic Systems, Inc., has been named general manager of the new Range Systems Div. **Robert C. Katkov,** and **Lawrence L. Kavanau** have been named managers of vehicle engineering and engineering research, respectively, in the Tactical Weapon Systems Div.

James A. Ross, vice-president and chief engineer at Ling Electronics, has assumed over-all responsibility for engineering policy at the company's Culver City and Winchester plants.

Col. Richard B. Robbins (AF-Ret.) has joined the Rheem Mfg. Co. Defense and Technical Products Div. as executive adviser.

Bernard Litman and **Wen Tsing Chow** have been appointed assistant chief engineers for research and missile guidance, respectively, at Arma Div. of American Bosch Arma Corp. Litman was project head of inertial equipment, and Chow, project head, computers and systems.

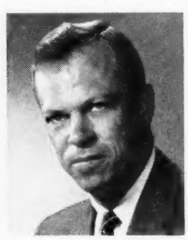
Frank B. Jewett Jr., vice-president, Vitro Corp. of America, has been elected executive vice-president, succeeding **Adm. Albert G. Noble,** (USN-Ret.), who will continue as a vice-president and devote his efforts to Vitro's R&D activities in the national defense field and establishment of a weapon systems group. **William B. Hall** becomes a vice-president, while **C. Dudley Fitz** becomes head of the

Friedman

Doll

Mueller

Thackwell



Puckett

Jones

Hoover

DeVore

Ambrosini

Webb

von Braun

Gross

newly formed Physics and Space Sciences Dept. at Vitro Labs.

Comdr. George W. Hoover, recently retired manager, Weapon Systems Air Branch, ONR, becomes director of technical planning for Benson-Lehner Corp.

Lloyd T. DeVore, former general manager of Stewart-Warner Corp. Electronics Div., has been appointed corporate vice-president and director of the new Hoffman Electronics Science Center.

Don L. Walter, former vice-president, engineering, at Van Nuys for Marquardt Aircraft, has been named to the new post of vice-president, Power Systems Group, while **Paul J. Papanek** becomes manager of the new Customer Relations Dept. for the group. **J. Louis Reynolds,** former director of customer relations, has been promoted to vice-president and assistant to the president.

Vice Adm. Truman J. Hedding (USN-Ret.) has been named technical assistant to general manager Donald L. Boyes of General Motor's Delco-Remy Div., where he will serve as executive representative on defense programs.

Arthur A. Fickel has been named manager of the Special Programs Section of General Electric's Defense Systems Dept.

Morrough P. O'Brien, dean of the College of Engineering at the Univ. of Calif., will retire, effective June 30.

Walter W. Mieher has been appointed engineering manager of Sperry Gyroscope Countermeasures Div.

Stanton L. Yarbrough has been made vice-president of The Gabriel Co.'s Electronics Div.

Leonard R. Ambrosini has been named to head the newly formed Analytical Engineering Dept. of Lear Astronic Div. and, in addition, will be responsible for certain R&D projects.

C. E. Oelker, former manager of missile systems at Avco's Crosley Div., has been appointed director of engineering, Bendix Aviation Cincinnati Div.

Brig. Gen. Frederick L. Hayden (USA-Ret.), has been named consultant for the Defense and Technical Products Div. of Rheem Mfg. Co.

Max W. Kistler, manager of aircraft products, has been promoted to vice-president of Kellogg Div. of American Brake Shoe Co.

August C. Esenwein, vice-president and general manager of the Ft. Worth plant, has been named executive vice-president of Convair. Other appointments are **J. G. Zevely,** director of contracts and commercial sales, to vice-president, contracts and commercial sales; **Elmer P. Wohl,** director of planning to vice-president, planning; **Frank W. Davis,** chief engineer, Ft. Worth plant, to vice-president and general manager there; and **Robert H. Widmer,** assistant chief engineer for technical design, to chief engineer.

J. Paul Walsh, former deputy director of Project Vanguard at the Naval Research Laboratory, has joined IBM's Military Products Div. as manager of Navy Programs in the Marketing Dept.

Richard A. Carpenter has been named manager of Callery Chemical Co.'s new Washington, D.C. office.

New appointments at Parker Seal Div. of Parker-Hannifin Corp. include **Paul F. Smith,** general manager of PS, to president of that division, and **Scott A. Rogers,** assistant general manager, to vice-president.

Paul Webb, chief of environment section and research physiologist, Aero Medical Lab., Wright-Patterson AFB, has joined Firewel Co.'s Aeronautical Div. as consultant in aviation medicine and environmental physiology.

Ronald Bell has joined Greer Hydraulics, Inc., as senior research physicist.

William T. Smith has joined the engineering staff of Narmco Industries Research and Development Div.

Henry S. Forrest has been promoted to vice-president of Control Data Corp. He formerly was director of government service engineering and manager of the eastern office at Washington, D.C.

Douglas Duke, former head scientist of the AFMTC satellite tracking project (Spacetrack), has joined Radiation, Inc., as a technical adviser in space technology.

Wensley Barker Jr. has been named staff engineer for Chandler-Evans Corp.

Albert E. Edwards, former vice-president, manufacture, Ford Instrument Co. Div. of Sperry-Rand Corp., has been elected a vice-president of The W. L. Maxson Corp.

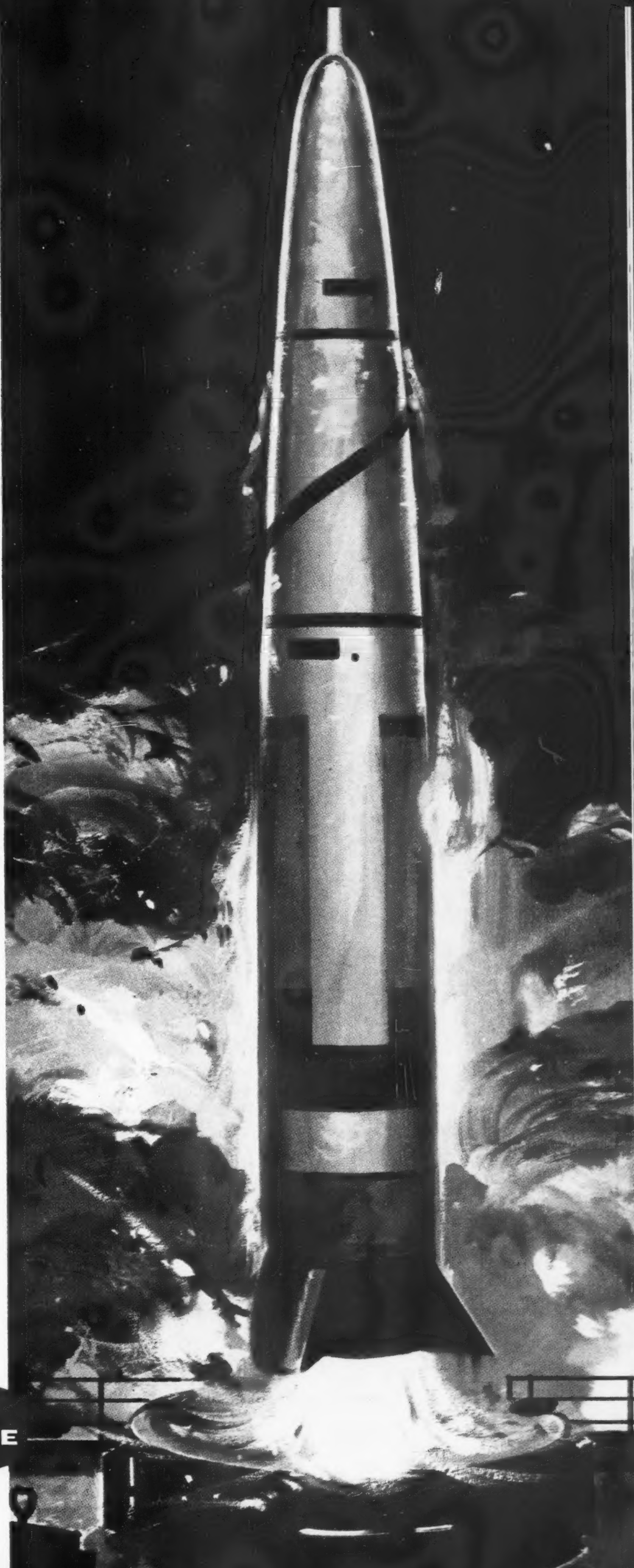
HONORS

Rocket and space pioneers took top awards at the IAS Honors Night Dinner. The first annual Lewis W. Hill Transportation Award of $5000 went posthumously to **Robert H. Goddard,** and was accepted by the American rocket pioneer's widow, **Esther C. Goddard,** one of the two ARS Honorary Members. The IAS John Jeffries Award for aviation medicine went to **Hubertus Strughold,** professor of space medicine and adviser for research, AF School of Aviation Medicine. **Charles S. Draper,** head of the Aeronautics and Astronautics Dept., MIT, was named an IAS Honorary Fellow.

Wernher von Braun, ABMA Development Director and ARS Board Member, has received the nation's highest civilian award, a gold Civil Service Medal. The award was presented to Dr. von Braun by the President on Jan. 20.

Robert A. Gross, chief research engineer of the Fairchild Engine Div., and immediate past president of the ARS Metropolitan New York Section, has received a senior post doctoral National Science Foundation Fellowship, and will take a year's leave of absence starting this August.

Charles E. Zimmerman, president of Consultants and Designers, Inc., has been presented with an outstanding public service award from the Army for the company's contribution to the successful launching of America's first satellite, Explorer I.



Hypersonic Aerodynamics

(CONTINUED FROM PAGE 25)

decelerations are experienced even if the re-entry is at grazing incidence. The trajectory is controllable to some extent if drag is controllable, but without lift the extent of such control is limited.

The skip vehicle obtains its range by a succession of ballistic trajectories connected by high-lift trajectories in the atmosphere. The principal idea here is that the kinetic energy is not completely lost upon re-entry, but after a certain attenuation in the skip process is used to establish a new ballistic trajectory. If it were possible to develop lift without drag, of course no energy would be lost in the skip process and the vehicle would have infinite range. Aerodynamic cleanness and a large ratio of lift to drag are essential for good range with a skip vehicle. In its over-all range performance, the skip vehicle has very similar, but not quite as good, characteristics as the boost-glide vehicle. In addition, the skip vehicle encounters high accelerations and intense heating during the skip process. The skip vehicle has been compared critically (and unfavorably) with ballistic and boost-glide vehicles by H. J. Allen, among others.

Booster Used

The boost-glide vehicle must be accelerated to a maximum velocity at an appropriate altitude by means of a booster system, which may be separable or not. After boost, the vehicle continues through the atmosphere toward its destination on a zero-thrust trajectory with constant weight. Its initial high velocity is reduced during the flight by aerodynamic drag. The vehicle must be supported by aerodynamic lift. The now conventional term "glide" is somewhat of a misnomer. A better term to describe the principal part of the flight would be "coast."

The sustained-propulsion vehicle is similar to a conventional airplane. It needs only to be initially accelerated to a relatively low operating velocity, that is, low compared with the initial velocity of a corresponding boost-glide vehicle. It must have an engine to provide thrust. And its trajectory is essentially one with drag balanced by thrust, with constant flight velocity. Since, presumably, fuel must be expended to obtain the thrust, such a vehicle has a continually decreasing weight. (A nuclear aircraft would fit into a special category, and is not considered here.)

Staging may be employed in the booster system of the boost-glide vehicle exactly as it is used for ballistic missiles: To obtain reductions of the ratio of takeoff weight to payload weight for a given mission. Analagously, staging may be used in the design of a sustained hypersonic airplane for the same purpose. It should be recognized that present-day refueling techniques are tantamount to staging, with the combination of tanker and airplane making up the first stage, and the empty tanker the returnable detached part of the first stage. Staging problems are of the design rather than the aerodynamic type, and are not considered further.

Range Performance

Let's look now at the range performance of these vehicles. The principal feature of range performance can be seen most clearly in comparison with the performance of a low-speed aircraft. All classical range and rate-of-climb performances may be looked at from the point of view of an energy balance. Engine thrust provides a source of energy, the drag a sink of energy. Energy may be stored by the aircraft as potential energy equal to Wh, with h the altitude, and kinetic energy equal to $\frac{1}{2}Wg^{-1}V^2$.

The classical range analysis for low-speed aircraft neglects the stored energy and simply equates thrust and drag. A more refined analysis may include consideration of the stored potential energy. The classical rate-of-climb analysis simply equates the excess power available with the rate of increase of potential energy. In either case, a characteristic feature of the analyses is that the kinetic energy is negligible in comparison with the potential energy. With the advent of higher velocities about two decades ago, a kinetic energy correction to the classical rate-of-climb formula became necessary.

With hypersonic speeds, the relative importance of potential and kinetic energy of the vehicle becomes reversed. The potential energy of the vehicle is now small compared with the kinetic energy. For instance, the potential energy of a body at an altitude of 200,000 ft is about equal to the kinetic energy of the body if it is moving at 3600 fps, but at thrice this velocity the potential energy is one-ninth the kinetic energy.

The range performance of a boost-glide vehicle may be looked at simply in terms of the attenuation of kinetic energy due to drag. A potential energy correction may be needed, of course, in accurate computations. With a sustained-propulsion vehicle at high speed, an increase or decrease

of speed during flight can have an important effect on range, just as an increase or decrease in altitude can affect the range at low speeds.

The curvature and rotation of the Earth have important effects on hypersonic performance, with the effect of the Earth's curvature being much more important. Neglecting the Earth's rotation, we may write Equation 1, as given in the table on page 25, with $\mathcal{R}$ the radius of the Earth. The equation shows the lift needed by a vehicle traveling at constant altitude or a constant small positive or negative rate of climb. At satellite speed $V = \sqrt{g\mathcal{R}}$, the lift needed is zero, and at higher speeds it is negative.

A simple formula (Equation 2 in the table) may be given for the range of a boost-glide vehicle under the assumption of constant lift-to-drag ratio (L/D) in terms of the initial velocity (V_0) at the beginning of the coasting phase. In this equation, the kinetic energy at the end of the range is assumed to be negligible. Equation 3 gives range for the sustained vehicle at constant specific impulse (I) of propulsion, constant L/D, and flight at constant velocity (V). Here W_0 and W_1 are the initial and final weights of the vehicle, respectively. In both these expressions range is directly proportional to L/D, and the importance of the concept of aerodynamic cleanness self-evident. The important effect of the curvature of the Earth at speeds of the order of satellite speed is self-evident in both expressions also.

If the boost-glide vehicle has constant C_LS at the specified constant L/D, it must fly at constant dynamic pressure. With V^2 decreasing with distance downrange, the density must increase. The flight trajectory is thus one of continually decreasing altitude. As we have indicated, the potential energy furnished by the altitude change is relatively small.

If the sustained vehicle has constant C_LS at its specified value of L/D, it must fly at continually decreasing dynamic pressure, corresponding to its continually decreasing weight. At constant velocity, the air density must decrease in proportion. The flight trajectory is thus one of continually increasing altitude.

An aircraft is normally expected to be controllable in the atmosphere and to be able to carry out certain maneuvers. The classical concepts of maneuvering take on some new aspects at very high velocities. The load factor in a turn is of the order of the ratio of the kinetic energy to the potential energy corresponding to an altitude difference of half the radius of the turn. Thus very high load factors are to be expected even in maneuvers whose dimensions are as large as the thickness of the atmosphere. Classical maneuvers such as Immelmanns and loops are not feasible in hypersonic flight. Besides the extremely large load factors involved in such tight maneuvers, there is a large loss of energy associated with any turn.

Simple Curved Flight

We will examine here only simple curved flight at approximately constant altitude, again neglecting the effect of the Earth's rotation. As with range performance, a distinction must be made between coasting and sustained flight, and account must be taken of the fact that the Earth's surface is curved. An uncurved flight path really follows a great circle on the Earth, and, in general, a complete turn requires turning less than 360 deg.

To simplify our discussion, we consider a vehicle traveling at constant latitude (θ) on an unrotating Earth, as indicated in the diagram on page 25. The (lateral) curvature of the flight path is tan $\theta/\mathcal{R}$, and a complete turn comprising 360 deg of longitude is a turn of sin θ times 360 deg. Equations 4 and 5 in the table on page 25 give the angle of bank (γ) where n is the total load factor equal to L/W. This load factor may be re-expressed as given by Equation 6 in terms of the latitude θ. At satellite speed $\gamma = 90$ deg and $n = \tan\theta$.

In coasting flight at constant weight, the velocity is constantly decreasing, and flight at constant latitude would be at constantly decreasing load factor. An expression for the range for such a trajectory may be obtained, but is not particularly instructive. For an example we consider the case of a tight turn with very large load factor and with γ essentially 90 deg. With L/D again assumed constant, we may derive Equation 7, where ϕ is the total angle of the turn in radians, equivalent to longitude if our flight is at a constant latitude near 90 deg.

Aerodynamic Cleanness

The effect of L/D in Equation 7 is an important one. The total angle of turn available in exchange for a given fractional loss in velocity or kinetic energy is proportional to L/D. Again, the importance of aerodynamic cleanness is evident. The same formula holds for the loss in velocity in a coasting turn at low velocity, but at low velocity changes in kinetic energy are not important.

In sustained-propulsion flight, the velocity is maintained constant, but the energy expended in thrust corresponds to a changing gross weight (barring nuclear power). At constant velocity the energy expended in thrust is simply IV times the decrease in weight. The classical Brequet analysis may be applied in this case. The result may be expressed in inverted form, as given by Equation 8, where ϕ is the total longitude angle in radians traversed by the vehicle.

An interesting feature of Equation 8 is that, at a velocity equal to $^1/_2\sqrt{2}$ or 0.707 times satellite velocity, the expenditure of fuel for a given longitude angle is independent of latitude. This feature of high-velocity flight was first found by Busemann in 1944, who noted that if L/D is fixed the energy expended in a local 360-deg turn is the same as that expended in a flight around the world. We may denote this velocity equal to $\sqrt{^1/_2\ g\mathcal{R}}$ as the Busemann speed, and note that at speeds higher than the Busemann speed a great circle trajectory is less expensive in energy or fuel expended than a local 360-deg turn, and conversely.

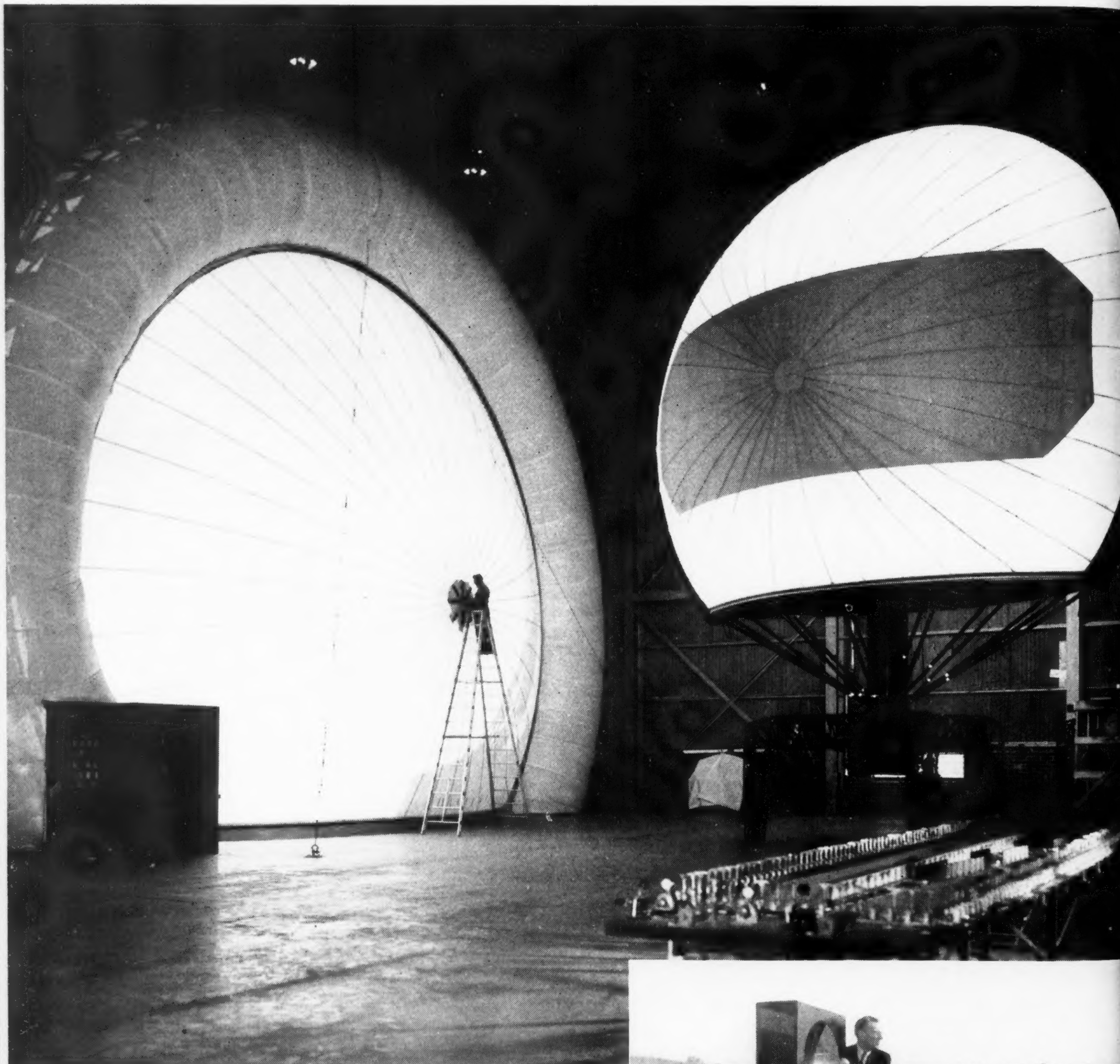
Part II of Dr. Hayes' discussion of hypersonic aerodynamics will appear in next month's ASTRONAUTICS.

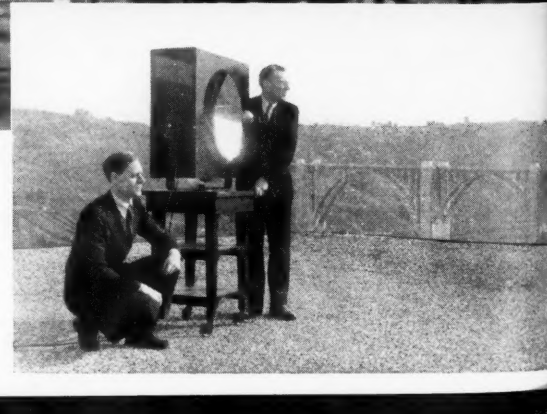
Explorer Training Models

These basic engineering models of Explorer I will be used by Army college ROTC units to acquaint students with missile technology. The models, manufactured by Ivel Construction Corp., Brooklyn, N. Y., measure about 7 ft long, 6$^1/_2$ diam, and are cut away to show major components.

APABILITIES FOR DEFENSE

Vestinghouse With 25 Years Of Leadershi Is Meeting Today's Detection Problems

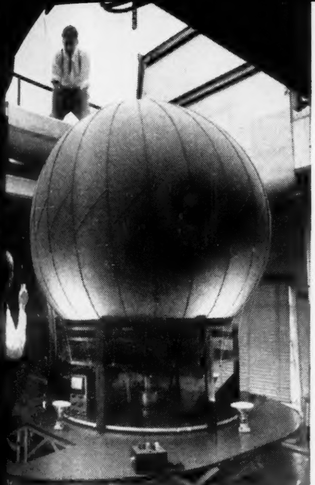




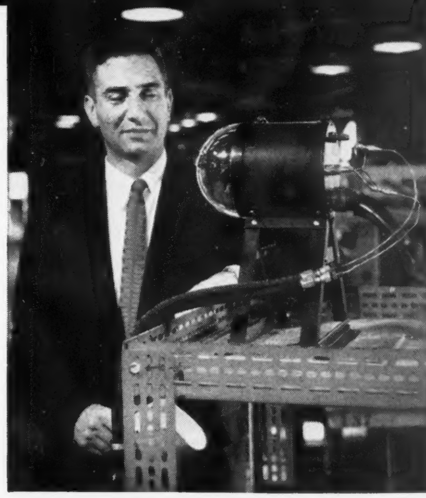
/estinghouse has been in the radar field since 1933. In that year, Westinghouse ngineers, pioneering in radar techniques, detected automobiles on a highway by eaming ultra short radio waves experimentally off a rooftop of the Westinghouse ast Pittsburgh Plant (illustrated at right).

/estinghouse has delivered over 35,000 radar sets . . . and continues its role today in round and shipboard radar for air defense and tactical missions, airborne radar r reconnaissance, AEW, mapping, ASW and missiles, and such specialized areas as ulse-doppler, infra-red, ECCM, and 3-D radar techniques.

hown is one of the most significant advances in the field of tactical military equipment—e lightweight, highly mobile Paraballoon® Antenna, developed at the *Electronics ivision.*



N-ROTATING ANTENNA. A new kind of lar antenna, the Helisphere is considered a sible forerunner of those to be used for werful antimissile radars of the future. The enna, pictured at the Westinghouse ***Research boratories,*** produces a rotating radar beam hout rotation of the antenna structure itself.



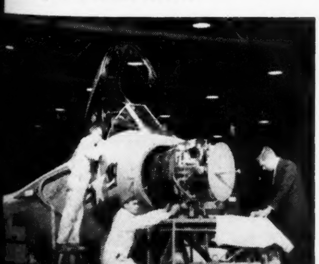
INFRA-RED. Westinghouse has been actively at work in infra-red research, design and development since World War II. Extensive programs are now being conducted for applications of infra-red techniques to present and future military requirements as well as the space age. Pictured is an infra-red seeker, newly designed at Westinghouse ***Air Arm Division.***

BIGGEST RADAR TUBE. Heart of the longest range sh borne radar ever put in service, a magnetron tube ni named "Big Maggie" was developed at the Westingho ***Electronic Tube Plant*** at Elmira. "Big Maggie" deliv over 10 million watts of peak power, enough to search enemy planes over 400 miles away.

LECULAR SYSTEMS. A new, low-noise ampli- developed by scientists at Westinghouse ***earch Laboratories*** for ***Air Arm Division*** ap- ation. This two level solid-state maser is one ect of a broad Westinghouse program of lecular engineering for radar and other tronic systems of the future.

WORLDWIDE SERVICE. Wherever Westinghouse radar is in operation . . . land, sea and air . . . field engineers of the ***Electronics Service Department*** assist and instruct in the operation and servicing of radar manufactured by the ***Air Arm*** and ***Electronics Divisions.*** Graduate engineers provide this Westinghouse service the world over.

COMPLETE TEST FACILITIES. Radar undergoes compos test at ***Electronics Division.*** A complete computer facil is available here and at ***Air Arm Division.*** Included c IBM 704 and large REAC, together with all environment shock, vibration and other test equipment necessary t the development of present and contemplated land, se air and space-borne systems.



0-MAN FLIGHT TEST FACILITY. Engineers at ir ***Arm Division*** install Aero 13-F radar and mputer, latest and most advanced radar built Westinghouse. Flight test facility includes r 200 people and all facilities necessary to mpletely service, instrument and test avionic uipment in Westinghouse owned and bailed craft.

For additional information on detection systems and applications at Westinghouse, write to:

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YOU CAN BE SURE... IF IT'S Westinghouse

International scene

BY ANDREW G. HALEY

Radio Allocations for Astronautics (Part I)

On the international scene, the first great progress in international cooperation is emerging through the foresight of the ARS Board in authorizing a vigorous campaign to preserve adequate portions of the radio spectrum for space communications. ARS was indeed farsighted, as the efforts to preserve radio spectrum for astronautics antedated President Eisenhower's announcement of July 1955, and, of course, the entry of any artifact into space. As a matter of fact, the first authorizations emerged from the meetings of the ARS Space Flight Technical Committee in 1952.

The task of prosecuting demands for radio spectrum space has been carried by the writer as ARS general counsel. The great scientific efforts behind the ARS proposals are the composite contribution of many ARS members. To say the least, the significant achievements have been the result of an ardent "labor of love" of all concerned.

In pursuance of this missionary work, the writer, armed with extensive scientific data from a large number of ARS members and other Societies affiliated with the IAF, traveled in August 1956 to Warsaw and participated in the proceedings of the eighth Plenary Assembly of the International Radio Consultative Committee [CCIR] of the International Telecommunications Union [UIT], Aug. 8–Sept. 13, 1956. Thereafter, the writer traveled to Moscow for the sessions of Study Group XI of the CCIR May 28–June 10, 1958, and to the Geneva CCIR meeting in August 1958.

° ° °

What are some of the immediate legal problems?

Within the framework of the pertinent international treaties, lawful use must be made of radio frequencies for all forms of astronautical communications. This requirement of international law has been observed only once by any nation since the launching of Sputnik I. Even during the past few weeks Lunik, or Mechta, broadcast on the most sacred of all frequencies, the worldwide allocated "standard frequency," better known as the time-signal frequency and also on the video part of television channel 8, used in Indianapolis, Des Moines, Syracuse, Cleveland, Portland, Dallas, Houston, and numerous other American cities.

As time goes on, the international obligations of the nations of the world will be more and more ignored—if the UN and UIT do not intervene. Many radio frequencies are needed for communication between Earth and vehicles in space, and between vehicles in space and Earth; between Earth and positions in space, and positions in space and Earth; between two or more positions in space; and between two or more space vehicles. Radio frequencies are essential, not only for all forms of communication between the fixed and mobile points, but also for numerous other purposes, such as telemetering, tracking, guidance, radiopositioning [radar], etc.

Any nation sending radio equipment into space (except equipment destined for probes beyond Mars and Venus) must be required to be able to command such radio equipment to stop transmitting, or the equipment may be the source of interfering signals for decades to come. With improvements in solar batteries and the use of outer orbits where sunlight is constantly available as the power source, radio equipment in satellites may in a very short time be capable of indefinite life, and therefore of indefinite interference, unless controllable.

° ° °

No object should be placed in any orbit in outer space which cannot be guided back to Earth or destroyed by some other means, such as being guided into the surface of the sun. The nations of the world contemplate sending scores of satellites and probe vehicles into space. Many of these undoubtedly will attain permanent orbits. Remember, it takes about as much energy to get one of these objects back to Earth as it does to place it into orbit initially.

As a practical matter, it would be almost impossible to divert an Earth-orbiting object outside the Earth's atmosphere without having placed on the object initially a mechanism with which to do the job. One cannot destroy the object by ordnance, since even if it were blasted the fragments would continue to orbit and probably become even a greater menace to navigation and safety in space. Therefore, international regulations are needed to insure that, before any object is sent into space, it must be equipped with apparatus whereby it may be commanded back to Earth, and to a safe location on Earth.

By the same token, any object sent into space must be under the control of the sender, so that, on completing its orbital life, the responsible party may guide the object back to an area safe for mankind. In other words, as satellites become larger, there is no assurance whatsoever that they will atomize on their return to Earth. The fact is that many of these objects will come back in large and lethal metallic chunks, and there is always the possibility that these metallic monsters will hit congested population areas.

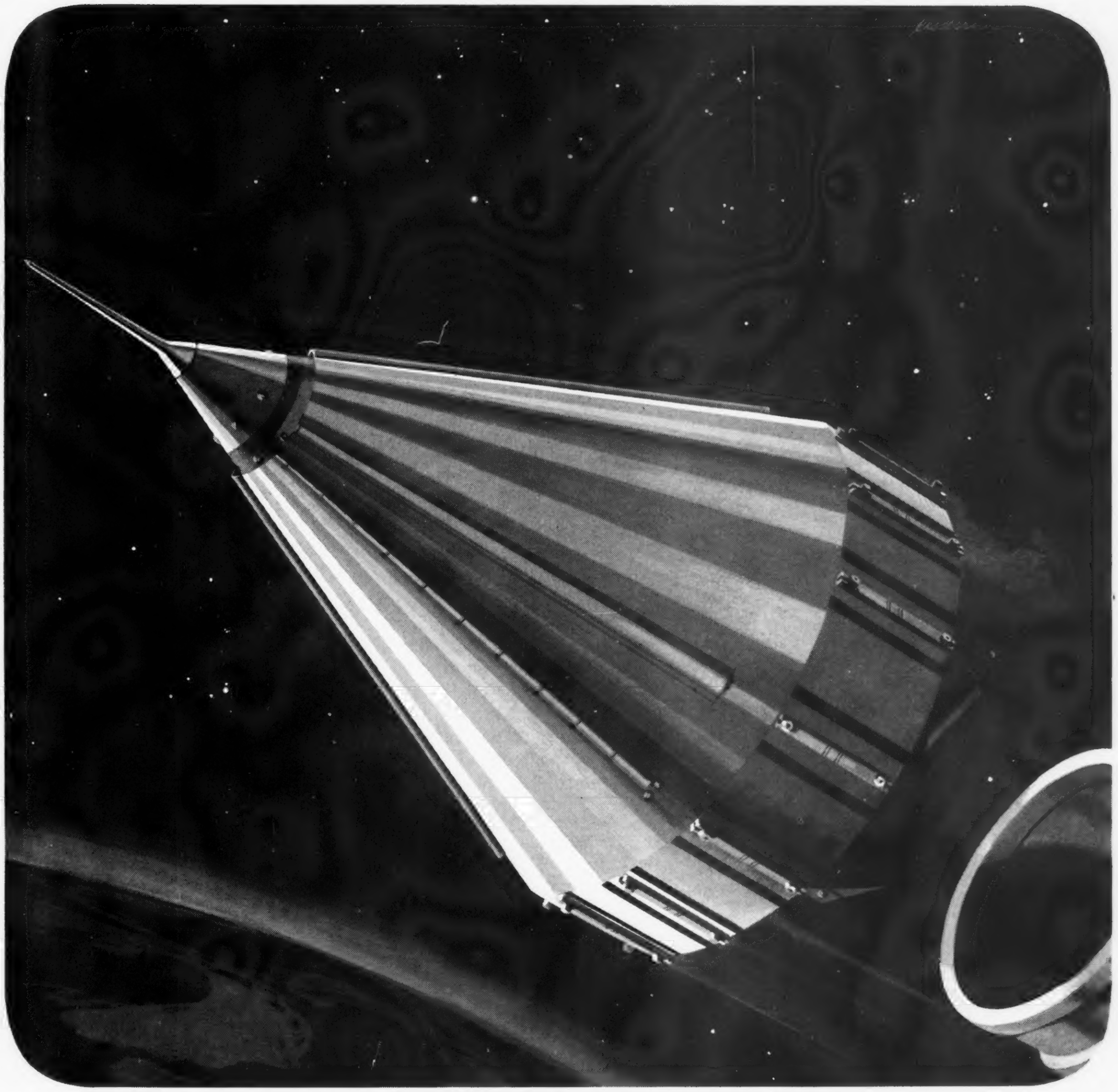
Assumptions of adverse odds really afford no criteria of safety. Only a few months ago, at Nellis AFB in Nevada, it was customary for jet planes to describe a run over a certain radio path, ascend high into the sky, and then perform the penetration dive. It was believed that this maneuver was entirely safe and that the odds that any mishap would occur involving commercial aircraft were so remote that notice should not be taken thereof. However, a United Airlines DC-7 in full (and cloudless) daylight, engaged in a routine scheduled flight, with more than 40 passengers aboard, was crashed into by one of these jets during the course of the penetration dive, and everyone aboard each ship killed.

We cannot assume that the returning debris of numerous satellites will not cause damage on Earth. It is fundamental that safety precautions be enacted and enforced. Of great importance to future manned space navigation is keeping "space ways" clear for the safety of life and property in space. This means we must provide now against all forms of space derelicts.

° ° °

ARS has submitted to the Federal Communications Commission several pleadings containing proposals for the orderly and lawful establishment of space radio services and the allocation of radio frequencies thereto, both on a domestic and an international basis. On Nov. 25, 1957, the Society filed comments in the FCC's Over-all Inquiry into Allocations in the Radio Spectrum between 25 and 890 mc. The Society made an extensive showing of need for the establishment of space radio services, and submitted a preliminary discussion of the frequency needs of such services.

(CONTINUED ON PAGE 87)



Japanese Wonder: Is Mechta Really a Dream?

By Robert Lawson

TOKYO, JAPAN: Two top Japanese tracking experts, balked in their efforts to track the Soviet lunar rocket, now reportedly orbiting the sun, are asking: "Is Mechta really up there?" The two experts are Yoshiaki Nakada, head of the Postal Ministry's Radio Research Lab, and Prof. Takeuchi of the Tokyo Astronomical Observatory. Their doubts arise out of the fact that no signals from Mechta (Russian for "Dream") have been received in Japan nor, as far as they know, in any other country.

Dr. Nakada noted that the three satellite tracking stations established by the Radio Research Lab last year are easily capable of receiving 10-w signals from the moon, 225,000 miles away. However, efforts made on Jan. 3 and 4 to pick up radio signals from Mechta on the wavelengths the Russians said were used for transmission were of no avail, despite the fact that there was little interference and radio reception was unusually good.

Two reports that radio signals from the vehicle were picked up in Japan proved false, Dr. Nakada noted. Later, either the rocket was on the other side of the Earth from Japan, radio reception was bad or the rocket had passed out of range, and the signal could not be picked up, he added.

What particularly bothers the Japanese is that they have been able to pick up signals from every satellite or probe vehicle launched to date, even including the small Vanguard test satellite, with its power output of only 5 mw and 2500-mile apogee. There is therefore no reason why signals from Mechta should not have been received, Dr. Nakada explained.

Prof. Takeuchi noted that the world's largest radio-telescope, at Jodril Bank, in England, had been unable to sight the rocket on Jan. 4, while the Tokyo Observatory, acting on a request from the Smithsonian Astrophysical Observatory, had made efforts to track the vehicle visually on Jan. 5. Using Russian launching data, the orbit was calculated and the observatory's 26-in. telescope, with its Schmitt camera, aimed at the clearest portion of the sky. All-night observation failed to turn up anything.

Prof. Takeuchi added that, even if the rocket exists, and has orbited the sun, it is extremely doubtful that the Russians have managed to plot its course accurately. This means that, even if Mechta returns to the vicinity of the Earth in five years, it is unlikely that any trace of it will be found in the heavens.

Need Additional Information

Both Dr. Nakada and Prof. Takeuchi pointed up the need for additional Russian information concerning the location of launching sites, radio transmission times, etc., as well as a full description of the rocket's trajectory.

"At present," they said, "we have to rely on the Russians' claims, and cannot acknowledge the existence of the rocket on the basis of our own findings. Looking at it from the basis of past Russian achievements, it should have succeeded, but data released to date are too rough and sketchy."

A spot check of leading U.S. tracking facilities at the end of January revealed skepticism over the Japanese skepticism about the existence of Mechta, but also showed that there were few, if any, confirmed tracks, either radio or visual, of the Soviet lunar probe vehicle.

Fred Whipple, director of the Smithsonian Observatory, earlier in the month said two photographs of what might have been Mechta had been taken by visual tracking stations, but there had been no confirmation on either photo.

Dr. Whipple also said that, if it proves impossible to confirm the fact that the photos are of Mechta, it would be extremely difficult, if not impossible, to spot the satellite when it returns to the Earth's vicinity in the future.

NRL and AF Data

NRL got only two tracks of what it thought might be the vehicle, one from its Antigua station and another in Washington. While it was felt that these were Mechta tracks, since signals came in on the correct wavelength at the correct time, and have not since been repeated, NRL spokesmen could not say conclusively that the signals were from the probe vehicle.

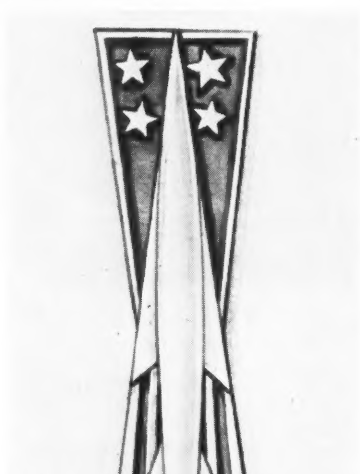
AF data were also scanty, the vehicle's flight path taking it out of radio range before definite confirmation of tracks became possible.

Radio tracking of probe vehicles, an NRL spokesman noted, requires extremely large antennas, only a few of which are available in this hemisphere, where the most extensive radio tracking systems, Minitrack and Microlock, are designed primarily for Earth satellite tracking. This, added to the usual Russian reticence about launch times, launch sites and trajectory data, makes the problem an extremely difficult one, and could easily lead to sighting errors. This might explain missing radio signals from the vehicle.

It is possible that the Russians bit off more than they could chew with Mechta, that they especially lacked the means and preparation to track their probe adequately. For the British Broadcasting Co. reported monitoring a Tass appeal to groups in and outside the U.S.S.R. for any tracking data: "The President of the Academy of Sciences of the U.S.S.R. appeals to all organizations and radio amateurs that made recordings of signals from the cosmic rocket to report them to Moscow."

—I.H.

AF Guided Missile Insignia



Air Force missile personnel will be easily distinguishable by a small silver badge worn on the left breast pocket of the uniform, depicting missile rising vertically to penetrate a cluster of four small stars. AF expects to issue the insignia this month.

Lobber Up Front

This rocket, under development by Convair for the Army, will be used to lob food, ammunition, etc., to front-line troops.

AGARD Announces Meetings Schedule through June

AGARD has announced the following meeting schedule for the first half of 1959:

March 2–5, "Interference Effects in Aerodynamic Test Facilities," Wind Tunnel and Model Testing Panel, Brussels; April 13–18, Materials Panel, Paris; April 20–25, Structures Panel, Paris; May 11–15, "Medical and Human Engineering Aspects of Flight," joint meeting in Athens of Aeromedical and Flight Test Techniques and Instrumentation Panels, covering escape and survival techniques, flight in nonconventional aircraft and psychopathological stress problems in flying personnel; June 7–9, "Full-Scale Testing, Structures Fatigue," Amsterdam; and June 8–12, "Chemistry of Propellants," Combustion and Propulsion Panel, Paris.

Heat Protection

(CONTINUED FROM PAGE 29)

To obtain the average heat input per unit area, it is still necessary to know the ratio of gross weight to surface area subjected to heating. Since this number varies from vehicle to vehicle, a not unrealistic loading of 100 lb per sq ft will be arbitrarily selected. On this basis, then, typical heat inputs for our re-entry vehicles are respectively 6800, 13,000, and 25,000 Btu/ft^2.

Length of exposure to heating must still be included among the inputs. Again, for convenience, an arbitrary number, corresponding to an *average* deceleration of 1 g is used. To decelerate from 26,000, 36,000, and 50,000 fps at 1 g requires about 800, 1100, and 1550 sec, respectively, and our average heat fluxes are 8.5, 11.8, and 16.1 Btu/ft^2/sec.

These are, to be sure, idealized, average values, associated with an idealized trajectory. Being averages, they ignore the higher values occurring in localized regions like noses and leading edges. The heat protection of these special areas will be discussed below.

Four types of heat protection are of interest for re-entry: Heat sinks, radiation cooling, ablation, and transpiration cooling. Taken together, they offer promise of solution of any likely manned re-entry heating probem; for, as will be shown, the ideally functioning heat-protection system may be a combination of the characteristics of several of the types.

The heat sink is a "low-temperature" system, operating below the melting temperature of the material. Absorbing heat by conduction from the surface, the sink works effectively only if the heat flux is no greater than can be accommodated by conduction. For the long times of manned re-entry, rate of conduction is not critical, and the heat-sink capability can be rated as the number of Btu absorbed per pound-weight in heating to the melting point. Values for appropriate materials are given in the table on page 29.

The longer the re-entry, the more connection with this table. First, with the sink heated all the way through to the melting temperature, it has no strength. Consequently, some sort of thermal insulation and structure is required inside the vehicle. Second, the weights derived from the table on page 29 (exclusive of insulation) for the re-entries we are considering would vary from 45 to 167 lb per sq ft for copper to 1.66 to 6.1 lb per sq ft for graphite, if these materials were used strictly as heat sinks. Actually, the weight can be considerably less because of re-radiation of heat.

The longer the re-entry, the more attractive cooling by radiating the heat off into space becomes. The temperatures required to dissipate the average heat fluxes of our re-entries are only about 1600, 1770, and 1950 F, respectively, for perfectly emitting surfaces. These are the so-called "equilibrium temperatures"—the temperatures that thin, perfectly insulated, black surfaces would reach during the defined re-entries.

The concept of a thin, high-temperature, radiating skin supported by insulation around the re-entry body for heat protection is a tempting one, and one which should be approached with caution. Unlike the heat sink, for which, at the low fluxes considered here, the rate of heating is unimportant, the thin radiating shield is critically dependent on the maximum heating rate encountered.

A momentary high rate of heating, as the result of a poorly guided approach to re-entry, for example, would cause a high surface temperature which might be disastrous. By contrast, the margin of safety for a non-rate-dependent system, designed to take the total heating, increases for deviations from the design flight plan, because any deviation decreases the L/D and hence the heating. Studies will evidently be required in this area to determine how a reasonable safety factor can be defined.

Safety Factor

The safety factor for ablation cooling systems, at least for transient excessive heat fluxes, comes from their built-in stability. The rate of melting or vaporization or burning adjusts automatically to the rate at which heat comes in. An increased heat flux is, as it were, "blocked" by the increased ablation. Ablative-cooled re-entry bodies are not new; ablating meteorites have been re-entering for centuries. Meteorites also give clues as to what materials are good and what are poor for ablation. Thus, stony meteorites appear in relatively good shape when recovered, whereas iron ones are badly pitted and eroded, as shown on page 29.

Several aspects of re-entry make ablation cooling attractive, among them the extremely high temperatures generated around the body. These temperatures are so high—perhaps 20,000 F—that chemical bonds of materials encountering the temperatures are broken, and the breaking of the bonds generally is accompanied by the absorption of large quantities of heat. For example, the dissociation of the hydrogen molecule to atoms results in a so-called endotherm of over 100,000 Btu/lb of hydrogen.

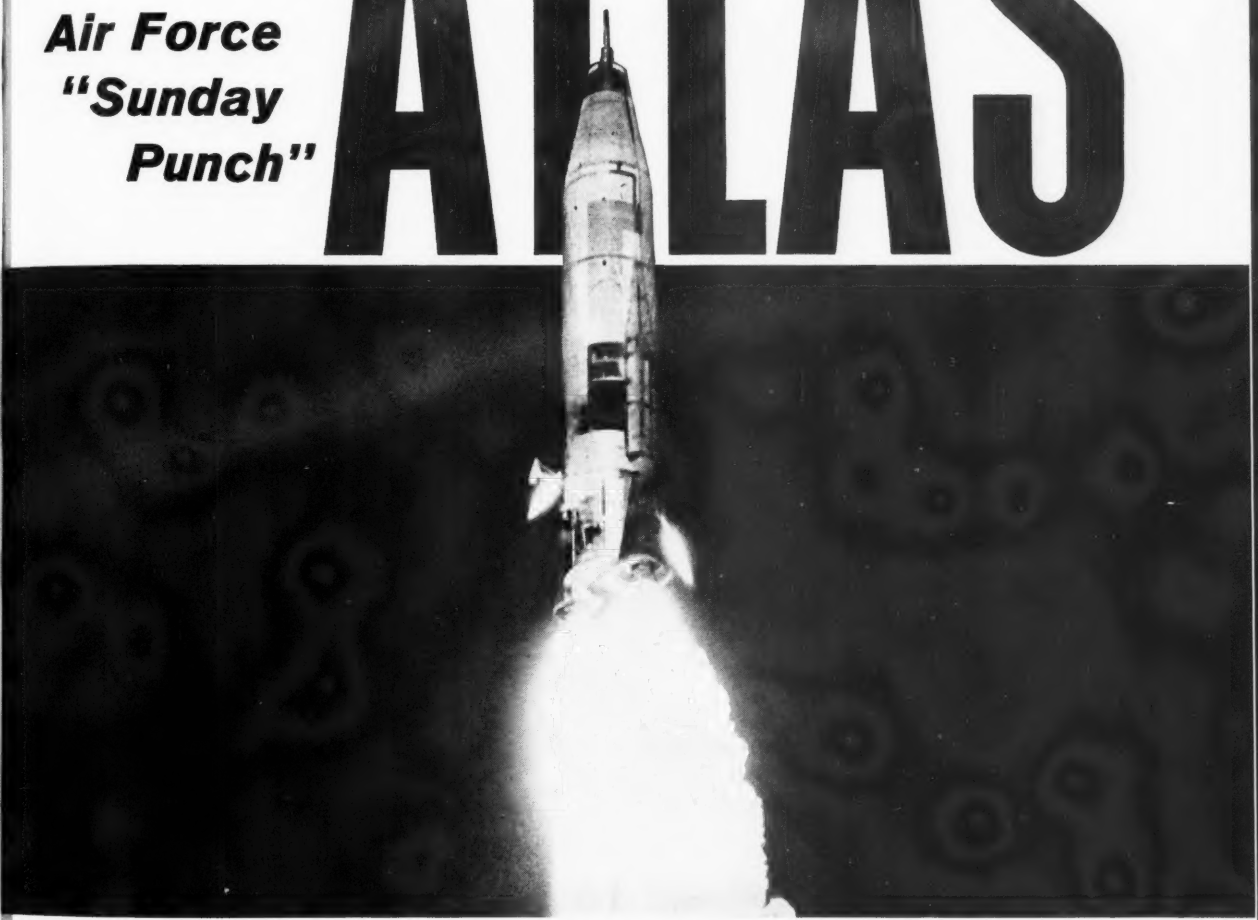
Building a heat shield of hydrogen molecules is not easy, but it is not difficult to find a number of reasonably satisfactory ablation materials. What is difficult is to evaluate the thermodynamic performance to be expected. The most promising tool for this is the high-pressure plasma jet, which can produce temperatures and pressures which are a good simulation of re-entry.

Facilities of this kind are new, yet it is possible to speculate on the implications of early results from them. First, the likelihood seems poor of achieving heat-absorptions of 100,000 Btu/lb, but good of achieving such capacities that the 50,000-fps re-entry

Preserver of Peace . . .

ATLAS

Air Force "Sunday Punch"



Boosted into space by the fiery thrust of three huge rocket engines, the seven-story Atlas intercontinental ballistic missile roars upward from its Cape Canaveral launching pad. Quickly it sheds the frost encrusting the liquid oxygen tank and races to its predetermined destination in the far reaches of the globe. In its size and range and capability, the Air Force Atlas is a commentary, for all the world to heed, of the necessity to maintain the peace. RCA's Missile and Surface Radar Department has been privileged to design and develop ground check-out, launch control and cabling equipment as a major subcontractor to Convair (Astronautics) Division of General Dynamics Corporation, the Atlas prime weapons systems contractor.

RCA Tmk(s) ®

RADIO CORPORATION of AMERICA

DEFENSE ELECTRONIC PRODUCTS
CAMDEN, N. J.

heating can be taken care of without excessive weight. Part of the explanation of the high effective heat absorption expected of ablation is that decomposition products from the ablated material tend to block the input of heat.

Cooling by the addition of matter into the boundary layer near the hypervelocity surface has been considered for years. Methods for doing this have generally used a porous metal or screen through which coolant has been forced or "transpired." The coolant usually considered is water, which should absorb better than 1000 Btu/lb.

Tests confirm the effectiveness of transpiration cooling, but the difficulties of translating from test to flight with the plumbing needed to distribute coolant over a substantial area have caused delays in its adoption. Two facets of transpiration systems which tend to be overlooked, however, merit further exploitation. These are that, with transpiration cooling, aerodynamic contours are not changing in flight, as they must be with ablation, and the surface temperature can be kept low by adjusting the flow of coolant. The first of these is important for leading edges and control fins, for which the local heat transfer may be high and the profile critical. The second is important because it helps to hold down the inside temperature.

After all, the inside temperature is most important. Something equivalent to thermal insulation is therefore always required. Insulation requirements seem to increase with the potential effectiveness of the heat protection. Indeed, the most effective reradiation systems necessarily work at the highest temperatures and so require the best insulators.

Insulation Needs Protection

Insulation materials are available with conductivities less than that of air, but in general these materials cannot operate at temperatures as high as required for much re-radiation. In consequence, an insulator is still needed to protect the insulation.

The importance of insulation is particularly evident at hot-spot areas, like leading edges. Consider, for example, a hot spot such that the heating is 10 times the average, say, 100 Btu/ft^2 sec, protected by a material like fused quartz as a re-radiating shield. Analysis shows that the thickness of material needed depends upon the inside temperature allowed and re-entry velocity, as shown in the graph on page 29. Thus, the thickness decreases for any velocity as the allowable inside temperature rises, and de-

creases at any allowable temperature as the re-entry velocity decreases. The required thickness is reduced two-thirds—to a reasonably low value—if the quartz-like material has the conductivity of an ideal insulator. The achievement of such a conductivity presents a real challenge in materials development.

Indeed, the real solution to the heat-protection problem must come through the development of materials. Unique properties are needed, and speculations about ways to achieve them are not unprofitable. The requirements are: Emissivities and surface temperatures high enough for good reradiation, adequate strength, good insulation properties below the surface, and short overheating not disastrous.

Many materials meet one or more but not all of these requirements. Graphite, magnesium oxide, fused quartz—a number of refractories, as shown in the table on page 29—have adequately high melting points. Some, notably fused quartz, also have adequate strength in the form of fibers like fiber glass. A potential exists, then, for meeting both the first and second requirements, even if refractory glues are not yet available to cement refractory fibers together. Furthermore, many of these materials should ablate well, being close relatives to stony meteorites.

But the development of an adequate refractory surface material is not enough to solve the problem. Insulation must also be adequate, particularly insulation which can backup the high temperatures without failure. Thus the ideal material must combine properties—form a system in a fashion similar to the way the ideal heat protection may combine the heat sink, radiation, and ablation approaches.

Final Analysis

In the final analysis, the heat-protection system must be integrated with structure in the best way possible. To some extent, accordingly, thermal characteristics must be compromised to improve structure. After surveying the thermal problems of re-entry, however, we should be optimistic that margins exist to permit compromises.

As has been shown, if re-entry is controlled to avoid excessive accelerations, excessive heating rates are also avoided. To be sure, if aerodynamic drag is used to slow the re-entering vehicle, velocities are limited somewhat—perhaps to 50,000 fps. Up to this velocity, heat-protection requirements do not seem to tax the potentials of materials provided that adequately refractory thermal insulation becomes available.

International Scene

(CONTINUED FROM PAGE 78)

Shortly thereafter, the FCC commenced a series of inquiries designed to elicit information to guide it in participating in State Dept. conferences preparatory to the 1959 World Radio Conference. ARS filed detailed comments in response to the first such notice. In those comments, the overall needs and characteristics of space radio were set forth. The Society's comments in response to the second notice of inquiry contained firm proposals for definitions of space radio services and stations and of space vehicles.

In response to the fifth notice, the Society filed a proposal for the allocation of various frequencies in the 20, 37, 100–150, 300, 450, 900, 4400, 10,000, 20,000, and 36,000 mc areas of the spectrum to space radio services.

ARS Works with State Dept.

ARS has also participated in the work of the State Dept. preparatory committees engaged in formulating the U.S. position at the 1959 World Radio Conference. In addition to attending and participating in working sessions of those committees, the Society, through the writer as general counsel, submitted a document entitled, "Some Proposals for the Allocation of Frequencies for Astronautical Services," to the State Dept. staff.

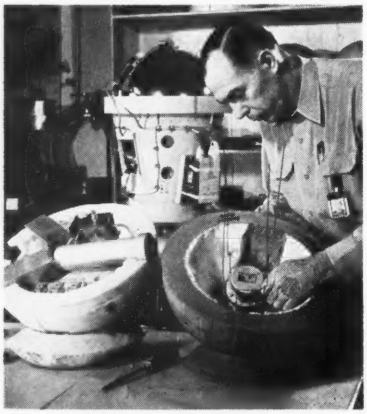
On Jan. 8, 1959, the FCC issued its sixteenth notice of inquiry, in which comments were solicited as to the FCC's specific proposals for Space and Earth/Space radio services. The Commission also asked for comments on its proposal for the allocation of certain frequency bands to the Space and Earth/Space services. The Commission proposes to allocate frequency spectrum between 25.6–25.65 mc to Earth/Space services; 100–150 to Space and/or Earth/Space services; 1700–1725, 1825–1850, 2275–2300, 8300–8400, 15,150–15,250, and 31,500–31,800 mc to Earth/Space, Fixed, Mobile, and Space services.

° ° °

In response to the Commission's request for comments on the proposed definitions of Space and Earth/Space services and stations, and on the proposed frequency allocations, the Society filed on Jan. 26, 1959 lengthy comments supported by the views of 30 technical experts.

The ARS comments will be summarized in Part 2 of this report in next month's ASTRONAUTICS.

Thor, Atlas Data-Recovery Capsules Successful



Capsules like the one shown being assembled, which tape-record telemetering data from Thor and Atlas nose cones before being ejected during re-entry, have been recovered with good data from all Thors and from one Atlas on which they were used, according to the Air Force. A capsule consists of tape recorder, radio-location equipment, and dye marker, all potted with urethane foam in a urethane sphere, this sphere in turn being within an ablating shell, which shatters off on water impact after re-entry. GE developed the capsule, Ampex the tape recorder.

Planning a Test Program

(CONTINUED FROM PAGE 31)

or discontinuity detectable is recorded for further consideration after flight. In this manner, the consequences of minor defects can be assessed after recovery of the flight nose cone. The nose cone is measured accurately so that any distortion or dimensional changes can be detected after recovery.

The inner wall of the nose cone is instrumented to measure temperature. When a nose cone is to be recovered, it is not necessary to use telemeter circuits for internal temperature measurements. Usually, the outer wall temperature, which does not lend itself readily to flight measurement, can be estimated from surface conditions after flight.

In this manner, a re-entry nose cone is readied for a full-scale flight test. But, as has already been suggested, this is only part of the program. Concurrently with the development of the insulation for the re-entry vehicle, the recovery program itself must be planned. A recovery program can be divided into two phases:

1. Development of recovery equipment and installation of the equipment in the re-entry nose cone
2. The recovery operation itself

Equipment necessary for recovering a test vehicle from water can be classified by function into retardation devices, flotation equipment, and location aids. The high re-entry velocity makes necessary some type of brake or retarding device—parachutes, parabrakes, or retro-rockets—to decrease the velocity and prevent damage to the vehicle at impact. Since the reentry vehicle is not likely to be structurally buoyant, flotation equipment, such as balloons or air bags, must also be provided. These devices are inflated just prior to impact.

Location Aids Important

Location aids, because of the possibility of adverse sea and weather conditions, are extremely important. Many different types of aids are used—colored balloons, dye markers, and flashing or steady lights for visual location; transmitter beacons for location by DF radio; depth charges for location by underwater sonar; and chaff or windows for location by radar. Of these, chaff seems to be the least effective for post-impact search purposes.

Development of recovery equipment which must be installed in a compartment of fixed dimensions and which must fall within certain weight limitations is in itself an engineering feat. To perfect the equipment to the extent that it will function reliably in a given sequence of events rigidly timed to fit into the last few thousand feet of flight requires considerable additional ingenuity.

Once a recovery unit is completed, it should be tested for reliability before attempting full-scale recovery. Nose-cone drop tests provide one effective means for establishing the reliability of the equipment.

The second phase of the recovery program, the actual recovery operation, can be divided into three major tasks: (1) Communications, (2) search, and (3) personnel training.

During a recovery operation, all information from pre-launch to final recovery should be controlled through one command position and disseminated to search units as required. Ample backup should be provided on all communication links to assure instant communications to all units.

Provision for and organization of sufficient search units is an extremely important part of the recovery operation. To make the search, an initial force of no less than three search ships and two planes should be in the impact area well in advance of the expected impact time. The initial search unit should be so well organized and trained that an area of 100 sq mi can be searched within a 5-hr period to assure a high probability of recovery even if a malfunction in the missile causes a considerable miss of the target.

Additional aircraft should be equipped and crews trained to continue the search should it extend past the initial 5-hr period. These aircraft should be on standby status throughout the operation.

Since all types of recovery operations will differ, recovery crews should be thoroughly trained in the operation of special equipment. Frogmen should be briefed on means of attaching lines to the re-entry vehicles to prevent damage, and such details as providing shark repellant in the nose cone for the protection of the frogmen should not be overlooked.

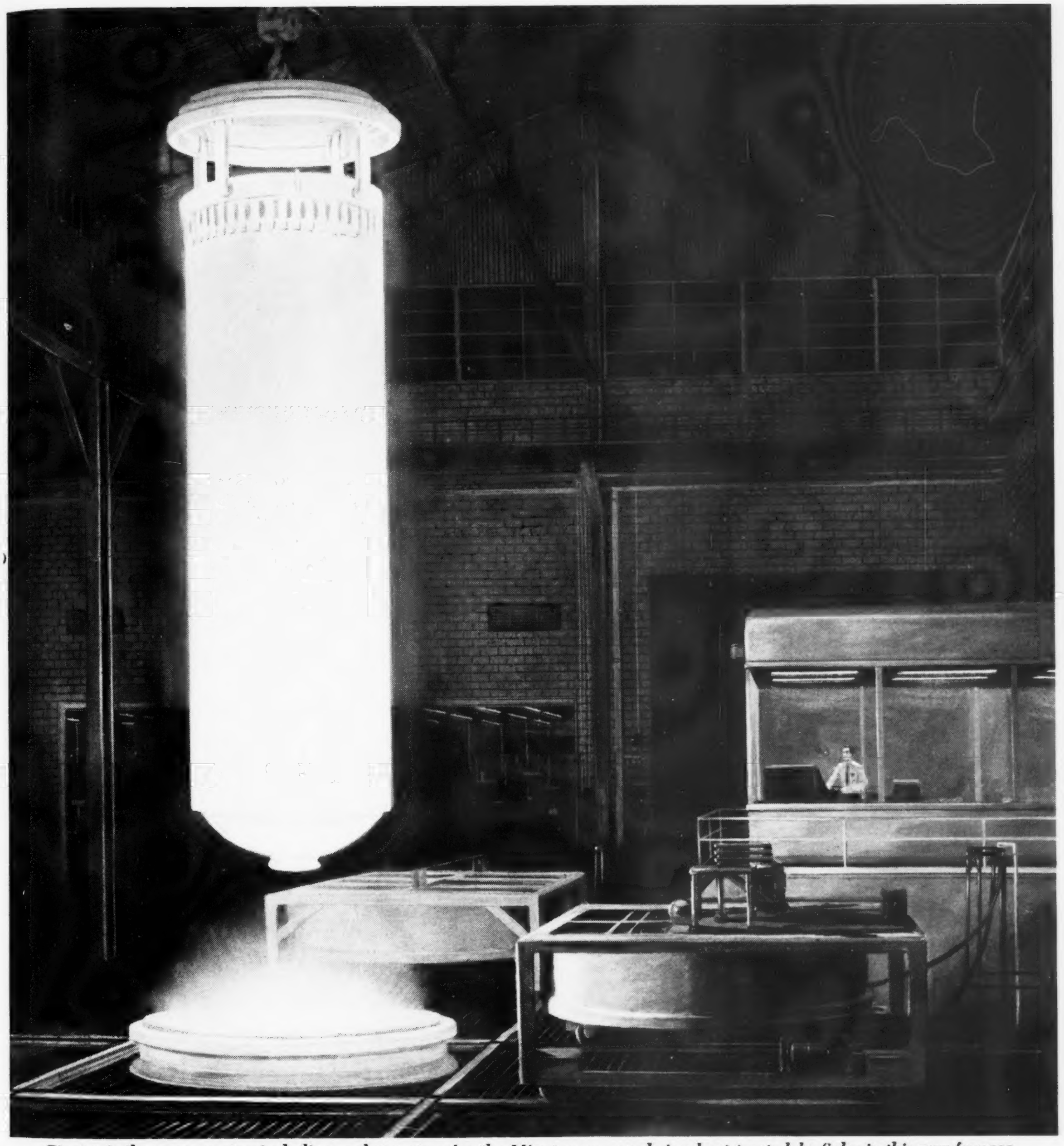
In any event, recovery should be preceded by a full rehearsal of the operation unless, of course, an emergency arises.

The recovery equipment and procedures described here have been tested successfully, using the Jupiter-C carrier vehicle (scale model re-entry cone) and two Jupiter carrier vehicles (full-scale IRBM missile nose cones). The most successful recovery operation was accomplished in 1 hr and 28 min. This was the time which elapsed between the Jupiter launching at Cape Canaveral and having the nose cone aboard the recovery ship hundreds of miles at sea.

Program Justified

Further recovery of re-entry vehicles seems fully justified, since visual observations of recovered vehicles permit a sound evaluation of defective areas, and hence contribute to the reliability of future re-entry vehicles. Moreover, the response of materials to the re-entry environment can be thoroughly studied, and this may lead to a reduction of the requirements imposed by allowing for a high safety factor. Study of the nose cone after flight is also valuable from the standpoint of surface temperature and flow conditions on the surface.

In an age when manned space flight is becoming a topic of everyday conversation, the demand for reliable reentry vehicles with attendant reliable recovery techniques is bound to increase. Such demands cannot be met without careful planning in every phase of a re-entry and recovery test program.



Giant missile components—including rocket motors for the Minuteman—are being heat-treated by Solar in this new furnace.

Missile Market

(CONTINUED FROM PAGE 44)

and its manufacturing facilities are among the most efficient in the industry. Also, Motorola's significant long-term potential has not been fully reflected by current market prices.

Eitel-McCullough is an important producer of power tubes, principally klystrons, sold under the trademark of Eimac. Its outstanding record exhibits substantial sales growth. During 1958, operations were adversely affected by increased research expeditures, the opening of a new facility and the effects of military cutbacks in 1957. However, last year was important in building for the future. During 1958, sales approached $15.8 million of 1957, although net income was well below the $0.89 per share of 1957.

In 1958, sales capacity was raised by at least 60 per cent through a new addition. Furthermore (new products were perfected by the company which should lead to significant sales. One important new area is the klystron tube for the Ballistic Missile Early Warning System. At the end of 1957, the company's backlog approached $5 million. This has risen by 40 per cent to $7.1 million at mid-1958. At the end of 1958, the backlog had reached a record level of $11 million with orders pouring in. For 1959, net income should at least equal the $1.52 per share reported in 1956. In the foreseeable future, with the continued emphasis on more powerful transmitting techniques, Eimac's sales and earnings should increase about 20-25 per cent per year. As a result, Eitel-McCullough appears to provide excellent opportunities for long-term capital gains.

Bendix Aviation was founded in 1929, mainly as a manufacturer of automotive parts, which presently account for only 15 per cent of sales. Electronics is now the fastest growing area and is the largest contributor to sales, with about 40 per cent of the total. Military sales, largely electronics and aircraft parts, account for more than 70 per cent of sales.

The strong Bendix research organization and manufacturing competence place it in an outstanding position to grow rapidly. Its diversity of experience and significant size are such that Bendix is one of the companies which can be an important prime contractor on large projects. Recently, Bendix was awarded the prime contract for the Navy's new Eagle air-to-air missile. The company also has a big stake in such promising areas as new electronic methods of weather forecasting, air traffic control, atomic aircraft, research reactors, and anti-submarine warfare.

For the fiscal year ended Sept. 30, 1958, net income declined to $4.18 a share from $5.44 a year earlier, reflecting a poor automotive year and defense cutbacks. Both these areas now are reversing these trends, and earnings this year should be much improved. The extent of present recovery, and particularly long-term potential, are not fully reflected by the current price. Accumulation by more aggressive long-term investors is recommended.

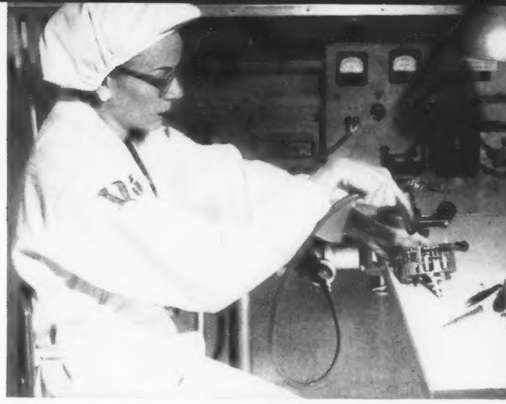
Black Enamel Armor for X-15

North American Aviation engineers chose a black enamel surface for the rocket-powered X-15 to radiate absorbed heat quickly. Highly heat-resistant enamel was developed by Rinshed-Mason of Anaheim, Calif.

(ADVERTISEMENT)

The unseen enemy

How Summers Gyroscope guards against the invisible anti-missile



Vacuum equipment at each of the 240 individual assembly benches helps insure product reliability.

There is an invisible enemy operating in many plants producing the missile components, flight instruments, gyroscopes and other hyper-sensitive devices on which much of America's power for peace depends. The strength of this unseen foe is potentially as great as that of any anti-missile missile.

Destroyer Of Standards

This reliability destroying, efficiency reducing enemy is dust, lint and other foreign matter. The slightest air borne contaminant coming to rest unseen on sensitive mechanisms during assembly can cause serious, even fatal deviations in performance. Production was often slowed until tests showed the system to be free of dust.

Dust Moved But Not Removed

To combat the dust dilemma at the Summers Gyroscope Co. plant in Santa Monica, California, personnel donned lint free jackets and hats — walked to their work benches in shoe bags. Temperature and humidity were controlled in an attempt to achieve an environment completely free of every possible contaminant ranging from stray hairs to perspiration. However, these precautions proved only partially successful when it was found that a manual dust gathering system in the final assembly "clean room" actually recirculated dust instead of removing it.

Double Duty Production Tool

For a solution to the dust menace, Summers called upon U.S. Hoffman Machinery Corp., pioneers in the use of air as a production tool. Hoffman engineers installed a permanent stationary vacuum cleaning system which provided for necessary cleaning operations at all of the 240 individual work benches in the 12,000 square foot final assembly area. Standard attachments made this same system available for cleaning overhead and under foot, all over the plant.

Before And After

Prior to the installation of the Hoffman stationary system, relative cleanliness tests were conducted. A microscopic analysis of slides revealed lint, dust and other foreign matter in excess of quantities allowable to maintain Summers' high precision standards. A short time after the Hoffman equipment was placed in operation, the same tests showed a truly dust free "clean room".

How It Operates

Heart of the stationary cleaning system at the Summers plant is a 60 hp Hoffman centrifugal exhauster producing the vacuum. A centrally located dust separator outside the assembly rooms collects the material with large filtering area insuring thorough cleaning of the air. Hoses for cleaning are inserted into strategically located inlet valves in the piping system conveniently located throughout the areas to be vacuumed.

Benefits And Advantages

Insuring spotlessly clean work in final assembly and calibration, the Hoffman stationary vacuum system already has paid for itself. It has helped Summers Gyroscope reduce rejects, maintain high reliabilty, increase production and improve employee morale. The Hoffman system enables Summers to meet and exceed specifications in supplying inertial guidance systems, flight instruments and gyroscopes to the U. S. Air Force, U. S. Navy, the Martin Co., McDonnell Aircraft, Douglas Aircraft and the Convair Div. of General Dynamics, among others.

If you have a special cleaning problem in your plant, ask for a free engineering survey to determine the most economical Hoffman system to prevent product contamination, salvage valuable materials, insure better housekeeping and encourage operating efficiency. Write for free booklet — How Stationary Vacuum Cleaning Systems Cut Costs, Increase Plant Efficiency.

U.S. Hoffman Machinery Corp.
Dept. A-1 Air Appliance Division
103 Fourth Ave., New York 3, N. Y.

Note how the Hoffman vacuum system handles both parts cleaning, (rear) and housekeeping chores.

A final assembly area is kept dust-free by the Hoffman vacuum system.

Communicating

(CONTINUED FROM PAGE 37)

values higher than that in the external shock layer. In this case, the majority of the attenuation might be due to the boundary layer.)

We have already noted that the medium in the shock layer has a conductivity comparable to that of semiconductors. The shock layer is therefore a poor medium for an antenna. Matching of the antenna to the medium cannot be obtained throughout the flight profile since the loading impedance varies. This loading impedance also determines the standing wave ratio for antenna feed.

It is also necessary to consider the effect of the shock layer medium upon the antenna radiation pattern. The free space pattern will be distorted, the amount and type of distortion depending on the operating frequency and the properties of the medium. These effects will vary along the flight trajectory. Under many conditions, most of the radiation can be shifted in the aft direction, and the forward-looking portion of the pattern suppressed. The degree of coverage with a ground station will depend upon the aspect of the ground station with the vehicle. The location for an antenna on the vehicle is obvious. It should be placed where the effects of the medium are least severe—namely, in the tail area.

By examining a specific vehicle flying a typical trajectory, we can illustrate the many aspects of the communications problem. Let's use for this purpose a so-called boost-glide vehicle, since the communications problem with this vehicle is much more acute than for, say, a re-entering satellite vehicle. The figures on page 36 depict a typical boost-glide vehicle and its flight path. The shaded area on the graph indicates the regime of flight where shock-layer ionization is significant.

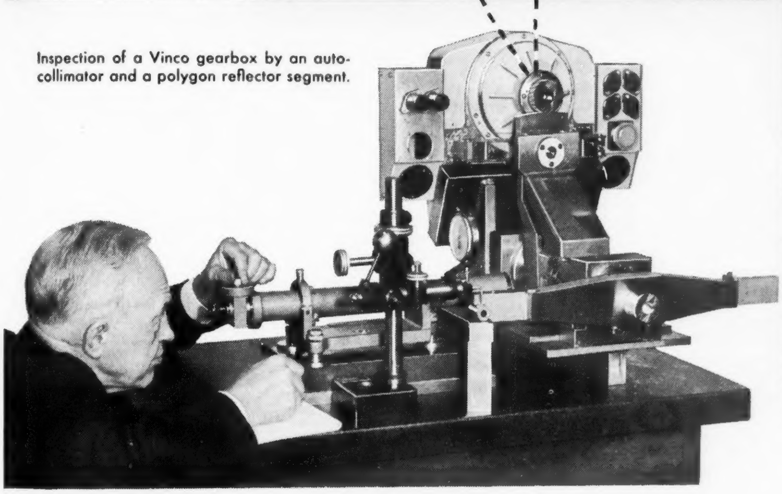
Let's put an antenna far aft of the nose on the underside of the vehicle. This placement is not entirely arbitrary since the further aft we are on the vehicle, the lower the flow-field temperature, and hence the less severe the attenuative properties of the plasma. To predict the degree of transmission difficulty, it is necessary to know the electrical and thermodynamic properties of the plasma at the antenna location for each point in the trajectory. In general, it is extremely difficult to compute the exact flow-field about a body traveling at hypersonic velocities. For simplicity, then, let's assume the glider may be represented as a flat plate inclined to the oncoming flow with a constant angle of attack. The trajectory for the vehicle will then be the one shown in the graph.

It is now possible, by standard techniques, to find the temperature and mass density at the antenna location as a function of position in the trajectory. Having determined these thermodynamic properties, one can determine the significant electrical properties of the plasma. These are the number of free electrons (N_e) in each unit volume of plasma and the so-called collision frequency (g). This collision frequency is the number of elastic encounters with particles of all species by each electron every second. Knowing N_e and g in a shock layer adjacent to the antenna, it is possible to calculate the attenuation of an electromagnetic wave of a given frequency as the vehicle proceeds on its flight path.

These calculations are straightforward. The procedure is to solve the electromagnetic wave equations with the aid of the following assumptions about the plasma and the radiation:

1. The shock layer at the antenna location is essentially uniform—that is, there are no gradients in the thermodynamic or electrical properties in a direction normal to the body.

2. The plasma is electrically neutral; the excess charge density in each unit volume of gas is zero. The electro-


Inspection of a Vinco gearbox by an auto-collimator and a polygon reflector segment.

Test stands for missile guidance systems include a gearbox built by Vinco to isolate the gyro system from the earth's rotation. Driven by an 1800 RPM synchronous motor, with a gear head stepdown to 1RPM, it produces an output motion of one turn in one sidereal day. Output accuracy limit of 3.6 seconds of arc reflects the action of 8 Vinco gears and 9 precision ball bearings. It is equivalent to .00018″ error of motion at the pitch line of a 32 diametral pitch, 20° pressure angle, 20.625 pitch diameter output sector.

Such accuracy is a must for checking the error or drift of gyroscopic and inertial guidance equipment. The gears in the sidereal rate test gearbox were ground and inspected on Vinco equipment by Vinco craftsmen. This personnel and equipment are available for producing gears of the same high precision for you.

The Vinco Optical Master Inspection Dividing Head is the most accurate instrument of its kind for checking angular spacing. Accuracy is guaranteed within a total variation of 2 seconds of arc (± 1 second). This instrument is available in both standard and heavy duty models.

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magnetic wave is plane polarized, monochromatic, and propagating in only one direction normal to the body.

With these assumptions, the following expression gives attenuation (ξ) in decibels per meter:

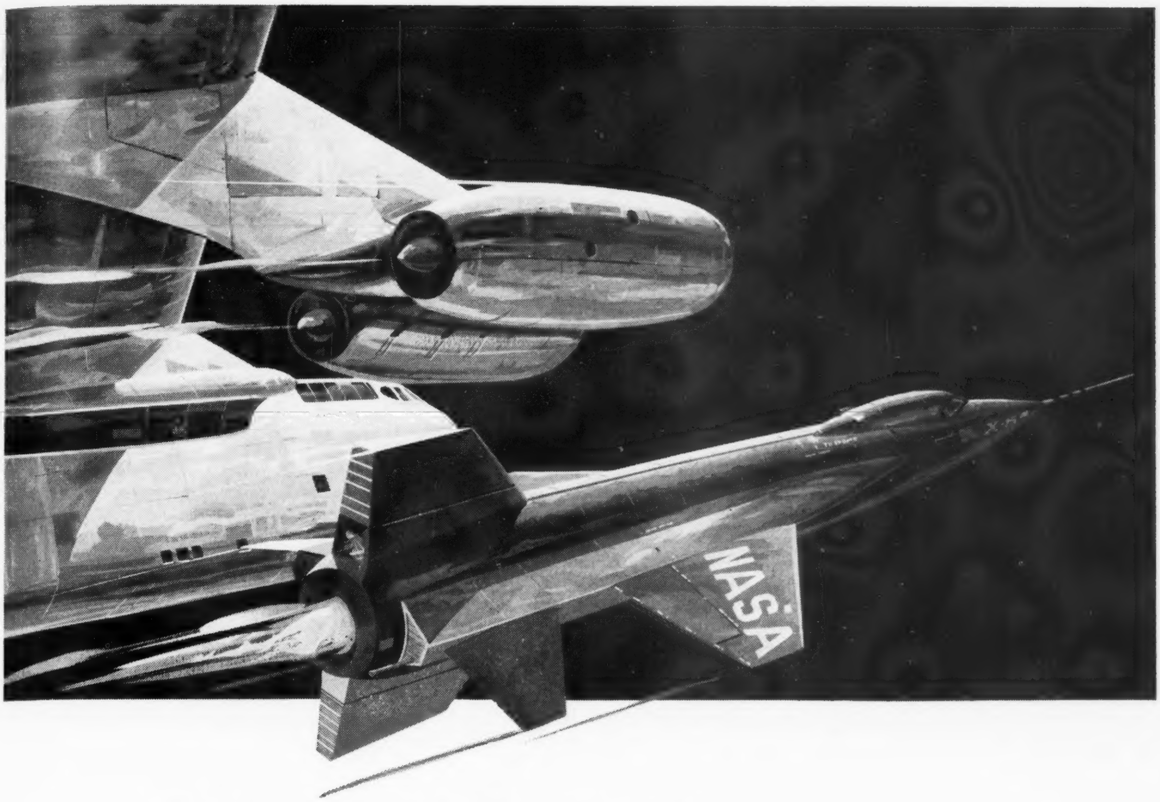
$$\xi = \frac{8.686\,\omega}{\sqrt{2}\,c}\left[\left(\frac{p^2}{\omega^2+g^2}-1\right)+\sqrt{\left(\frac{p^2}{\omega^2+g^2}-1\right)^2+\frac{p^2 g^2}{(\omega^2+g^2)\omega^2}}\,\right]^{1/2}$$

where c, the speed of light, is 3 x 10^8 m/sec; p, plasma frequency, is $3980\sqrt{N_e}$; and ω equals $2\pi f$, f being the transmission frequency. Appropriate values of N_e and g in this equation for a given transmission frequency allow determination of the energy-rejection properties of the plasma as a function of flight-path position. For the vehicle and trajectory under consideration, the graphs on page 37 show attenuation for transmission frequencies from 20 kc per sec to 20,000 mc per sec.

It can be seen that at low frequencies attenuation is not severe. However, almost all of the radiation would be reflected back to the antenna. At higher frequencies, reflectivity will decrease, but attenuation will still be prohibitively high. Finally, a maximum attenuation point will be reached, beyond which point transmission appears feasible. It should be noted, however, that unusually high frequencies are necessary to send a receivable signal.

Some brief remarks are in order about our assumptions. The thermodynamic and electrical properties of the plasma were calculated by assuming thermodynamic equilibrium was attained at each point in the flow-field. This implies that the inert degrees of freedom of all species present in the plasma adjust themselves to any change in intensive thermodynamic variables almost immediately, so that at every point in the flow-field the plasma composition is the equilibrium composition.

While the assumption of thermodynamic equilibrium is almost certainly a good one at low altitudes, it probably becomes one of doubtful validity at altitudes of 200,000 ft and above. Relaxation time for any degree of freedom varies inversely as the density and reaction rates would therefore be significantly lower at high altitudes than at low altitudes. The opposite extreme of thermodynamic equilibrium would be frozen-flow, where the reactions proceed very slowly, so that gas composition remains fixed at the value immediately behind the shock wave. If a frozen-flow situation were to exist, the attenuation and reflection problem would be worse in almost all cases than



the X-15

The 1-mile-per-second X-15, designed to carry its pilot into the fringes of space, is a product of joint efforts of NASA, Air Force and Navy, with close cooperation of North American Aviation, Reaction Motors and 300 other contracting firms. This aircraft —latest in a long-term program conceived by NASA scientists for the advanced study of the problems of flight—will make its first flights soon. NASA has technical direction of the X-15 project and will report the research results for use by Government and industry.

The X-15 is a *rocket research airplane*, a flying laboratory.

Primary research interest in the X-15 is to obtain knowledge of actual flight conditions in the near space environment, to produce a wealth of information from repeated missions involving entry into and exit from the atmosphere. And *only man* can prove how man will react in space to weightlessness and intense acceleration and deceleration.

The X-15 program is typical of the exciting things happening at NASA, whose responsibility it is to direct and implement U. S. research efforts in aeronautics and the exploration of space, for peaceful purposes and the benefit of all mankind.

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- **Ames Research Center, Mountain View, California**
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- **Beltsville Space Center 4555 Overlook Ave., Washington, D.C.**

(Positions are filled in accordance with Aeronautical Research Announcement 61B)

NASA National Aeronautics and Space Administration

for thermodynamic equilibrium flow.

The assumption of the flow-field uniformity at the antenna location is generally good for vehicles having geometries similar to the one described here. For other shapes, the blunt-nose effect may persist to the antenna station, and cause substantial gradients in the plasma characteristics in the direction of propagation. This situation could require a computer solution of the wave equations. All other assumptions appear to be of general validity.

How might problems of signal propagation be overcome or circumvented? Where a maximum flow-field temperature occurs within the viscous boundary layer, it should be possible to inject some foreign material which has an affinity for electrons (boundary layer poisoning), and thereby reduce the local electron density, thus making propagation less difficult. The value of this scheme would probably require an extensive research program.

In an opposite approach, it has often been suggested that the shock-heated plasma which enshrouds a hypervelocity vehicle could be used to advantage. The idea behind such schemes is to couple energy into the shock layer and use it as a radiator—that is, the intelligence would be fed from the transmitter through some "extra state of the art device" into the plasma, which would then act as an antenna. The authors cannot readily visualize the characteristics of the intermediate "device," and therefore are unable to assess the worth of the entire scheme. This area should be an extremely fruitful one for research.

High Frequencies Required

It appears that, despite hardware problems, the best way to defeat the propagation problem is to penetrate the attenuating plasma by brute force—that is, by using extremely high transmission frequencies.

During research and development, a hypersonic vehicle will require reliable communications and telemetry. The frequencies presently allotted for telemetry will be useless over most of the flight trajectory, owing to the expected high signal attenuations. Communications and telemetry will therefore require use of frequencies in the *K* and *Q* bands. Problems associated with the use of these frequencies and trade-offs necessary in system parameters between the ground station and the airborne link to realize a system of a certain degree of reliability are well known.

Use of these high frequencies will necessitate design and development of new communications equipment. For

telemetry, present techniques of modulation and detection must be reviewed and new techniques tested, the goal being a system of optimum reliability, power, and weight. Integration of the communications function with telemetry should also be considered due to the narrow bandwidth (10 cps or less) required by more than 90 per cent of the data sampled for telemetering. An integrated system would give the advantage of one transmitter and one antenna for both communications and telemetry.

Nature of Re-entry

(CONTINUED FROM PAGE 21)

sizing the heat rate limit as W_0/C_DA increases.

This "heat-rate limit" has a pronounced effect on nose-cone design. As W_0/C_DA is increased at a fixed range, the payload ratio will eventually decrease markedly, as shown in the top graph on page 21 for a typical set of long-range missile parameters.

The ablation, or mass transfer, approach to ballistic-missile nose-cone design is not "heat-rate limited" in the same sense as the solid heat sink. This can ameliorate the design problem considerably. In distinction to a solid heat sink, the ablative shield not only absorbs heat by its own solid-state heat capacity, but also may melt and then vaporize, thereby absorbing additional heat. Vapor "blown" into the boundary layer will further reduce the amount of heat transferred to the solid portion of the body.

For the present purposes we can assume this process is calculable, and define an effective heat ablation as follows: $Q^* = 1/\dot{m}\ C_{H_0}\ (\rho u)_e\ \Delta H$, where $\dot{m}$ = material ablation rate in lb/ft^2/sec; C_{H_0} = heat transfer coefficient from the boundary layer to a nonablating surface at the same temperature as the ablating surface; $(\rho u)_e$ = mass flow at the outer edge of the boundary layer in slugs/ft^2/sec; and ΔH = enthalpy potential across the boundary layer in Btu/slug.

Recent experimental work has shown that Q^*'s of several thousand Btu/lb are attainable. An ablative re-entry body can therefore be considerably more efficient than a solid heat sink. The differences in behavior between solid heat sinks and ablation heat protection systems are readily apparent from the top graph on page 21. The attainable W_0/C_DA for a given total weight has been increased considerably, and the absence of an abrupt cutoff in payload at low W_0/C_DA's is evident.

The problem of re-entry body design is not, however, simply a matter of aerodynamics and heat protection materials. There are also very strong interactions of the re-entry body with the accuracy of the missile guidance system and with the total effectiveness of the weapon carrier. To bound or define re-entry problems for ballistic missiles, one must also investigate these other constraints.

An important source of error in ballistic missile re-entry is the dispersion (σ_r) about the aiming point caused by unpredictable winds, atmospheric density variations, etc., in the vicinity of the target. A possible behavior of this error with W_0/C_DA is shown in the middle graph on page 21. If we also assume particular values of guidance dispersion (σ_G) independent of the re-entry body W_0/C_DA, the total error decreases with increasing W_0/C_DA.

Data Combined

If we now combine these data on payload ratios and accuracy to determine the effectiveness of a ballistic missile, certain interesting conclusions may be drawn. For example, assuming that a fixed weight can be delivered to the target area, we can determine warhead effectiveness against point targets as a function of W_0/C_DA.

The damage criteria for a point target can usually be stated as a certain overpressure (Δp) created at the target by the weapon explosion. As the distance from the center of the burst increases, the overpressure decreases until, finally, the minimum Δp for damage is reached at the "effective damage" radius (r_e). As a function of payload weight, r_e varies approximately as $r_e = K\ W_p^{1/3}$. Then the probability P of obtaining Δp on the point target for a single shot is approximately:

$$P = 1 - \exp - \frac{1}{2}\left(\frac{r_e}{\sigma_t}\right)^2$$

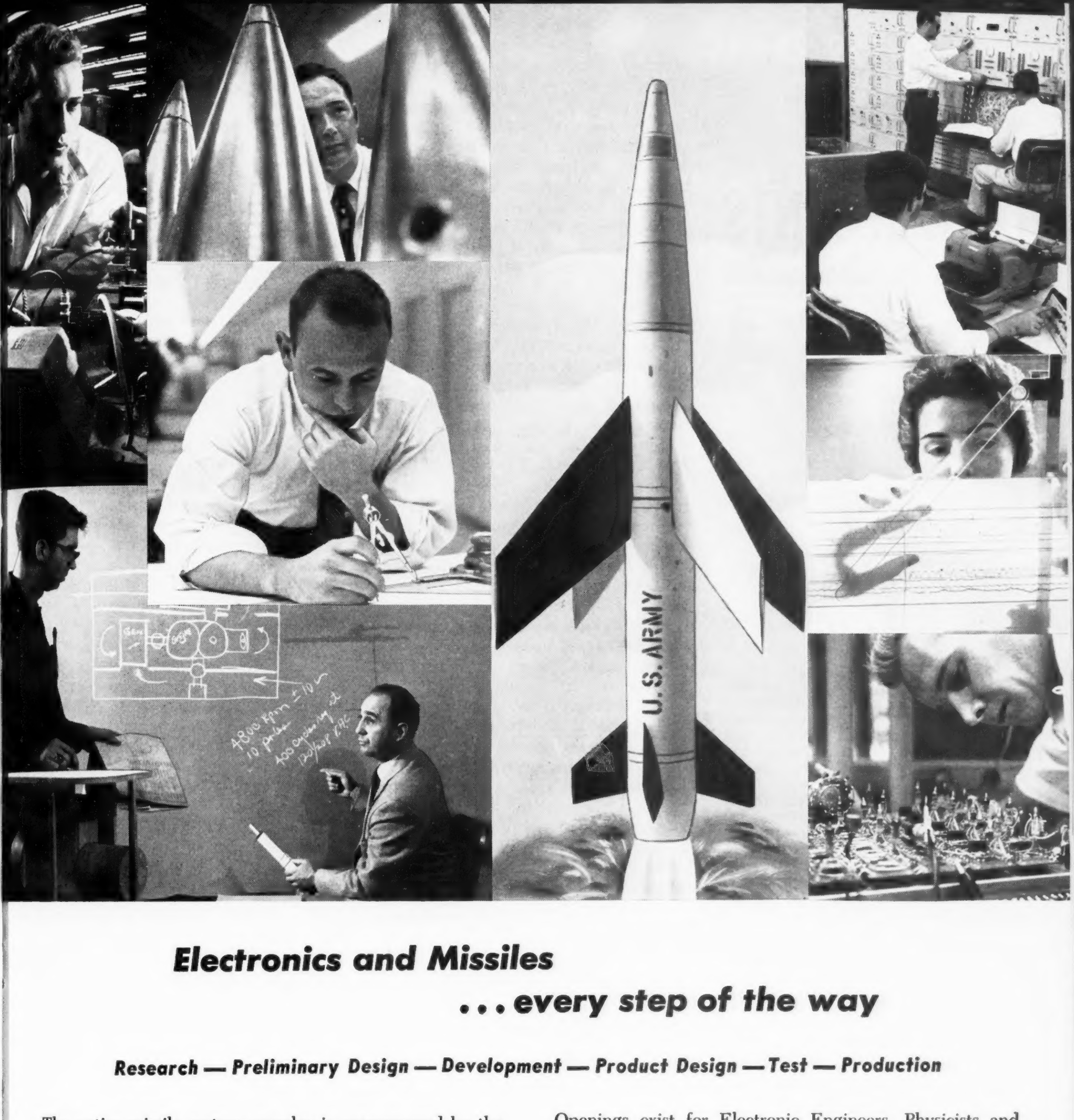
or

$$P = 1 - \exp - \frac{1}{2} K^2 W_0^{2/3} \frac{(W_p/W_0)^{2/3}}{\sigma_t^2}$$

where

$$\sigma_t^2 = \sigma_r^2 + \sigma_G^2$$

We shall define an "effectiveness factor" (E) as $E = (W_p/W_0)^{2/3}/\sigma_t^2$. The bottom graph on page 21 shows E as a function of W_0/C_DA for solid and ablative heat sinks and for two



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assumed values of guidance accuracy. While the value of the factor K cannot be given in this paper, the trends and relative values indicated on this graph are reflected in the point target damage probabilities. The advantages of an ablative heat sink relative to a solid heat sink are apparent.

The reasons for understanding and improving methods of heat protection can now be seen in strong relief. An appreciable improvement in the effectiveness parameter will increase the capability of the weapon system, thereby reducing the total force requirement. Therefore, a relatively modest investment in research and development can effect a total savings many times greater in magnitude. Conversely, this last graph also shows that, once a reasonably high W_0/C_DA ablative nose cone is developed, improvement of the guidance system may be more profitable than further nose cone development.

We have, to this point, attempted to demonstrate why there is a necessity to relate the problems of re-entry materials, heat transfer, and aerodynamics to the missile system in arriving at a logical design. Let's turn for a moment to space vehicle re-entry.

The problem of re-entry from space is, in general, more severe than ballistic missile re-entry in the sense that the total energies involved are greater. For example, a body re-entering from a 300 n.mi. circular orbit about the Earth has an energy of approximately 13,000 Btu/lb and, if returning from the moon, an energy of nearly 26,000 Btu/lb. In the space re-entry problem, however, the re-entry angle into the atmosphere is within the control of the system designer. Thus, total heating, heating rates, and deceleration loads can be adjusted to acceptable values. Since the heating rates and deceleration loads can be kept relatively low by selecting small re-entry angles, radiative cooling techniques, combined radiators and solid heat sinks, and even simple solid heat sinks and ablation are all possible solutions to the re-entry heating problem. The optimum solution, of course, depends on the particular design problem under consideration.

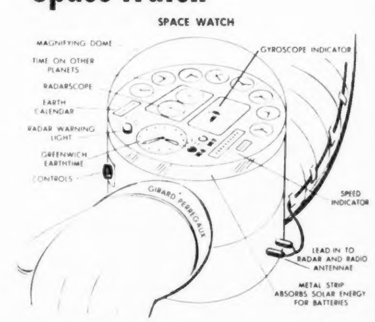
Space re-entry introduces a new problem, as compared with ballistic missile high-drag re-entry, in that a certain degree of directional or load control is often desirable. For example, manned re-entry to Earth from a lunar mission may require a re-entry body capable of generating lift forces. When a simple drag-decelerated body enters the atmosphere at a velocity of, roughly, 36,000 fps when returning from the moon, the design re-entry angle from the local horizontal might be approximately 5 deg at 400,000 ft. If, at re-entry, the angle became less than 4 deg, the body would "skip" out of the atmosphere, while, if the angle were increased to 6 deg, the maximum deceleration would increase to 20 g. Since the re-entry angle may be subject to somewhat larger variations than mentioned above, the use of lifting bodies to broaden these limits has been proposed and analyzed by Lees, Hartwig, and Cohen.

In brief, they show that if a lift to drag (L/D) ratio from $+2$ to $-1/2$ is attainable, the re-entry angle limits become approximately 0 to $9\,1/2$ deg without either exceeding 10 g acceleration or "skipping" out of the atmosphere.

Implicit in the above discussion of space re-entry is the assumption that drag dissipation will be employed to slow the space re-entry body and that some type of radiative cooling, mass transfer technique, etc., will be utilized to protect the vehicle from heating. An alternate method would be to slow the vehicle while outside the atmosphere with a propulsion system. However, an Earth satellite vehicle, say, can probably be designed to reenter safely and lose no more than approximately 10 per cent of its mass in slowing to nearly zero velocity from 26,000 fps. Thus, the effective "specific impulse" of drag deceleration in this example is approximately 7700 sec.

It is probable that "aerodynamic braking" will be with us for some time to come.

"Space Watch"



Solar energy will power this "space watch," designed by Lloyd Motz of Columbia University for Girard Perregaux & Co. Still in the drawing-board stage, the watch would not only tell Earth time and date, and time on other planets, but would provide a radar warning system for meteors, a radar speed indicator and a gyroscope to track direction.

Government contract awards

Space Capsule Instrumentation Job Goes to Collins Radio

McDonnell Aircraft, NASA choice to develop a space capsule for its Project Mercury, has picked Collins Radio Co. to produce complete electronic instrumentation for the program. Equipment will include radio voice communication, radio command system, and telemetry, guidance, tracking, and rescue-radio beacon systems.

$102 Million Contract Signed for 1.5 Million-Lb Booster

NASA and Rocketdyne have signed a $102 million contract for development of a $1^1/_2$-million pound thrust rocket that could launch satellites weighing several tons.

AF Boron Fuels Contract Goes to Stauffer-Aerojet

A $2 million Air Force contract has been awarded to Stauffer-Aerojet for production of high energy boron fuels, including design, construction, and operation of a pilot plant now being built at Aerojet's Sacramento facility.

Upper Stage for Atlas ICBM

An Air Force contract, with a first year value of $7 million, has been awarded to Convair-Astronautics for design, construction, and test of an upper stage for a modified Atlas ICBM. The vehicle's high-energy liquid propellant engine will be developed by Pratt & Whitney Aircraft.

Convair's San Diego Div. has received a $2.5 million ARPA contract for two major studies on advanced ballistic missile defensive systems. Convair Pomona Div. has been awarded a $31.4 million Navy contract for production of an advanced version of the Terrier missile.

Atlas Guidance Systems

Three contracts totaling $110 million were awarded by AMC's Ballistic Missiles Center to GE's Defense Systems Dept. for guidance systems that launched Atlas Score into oribt.

Snark Follow-On Order

The Air Force awarded Northrop Div. a $50 million contract covering production of additional Snark missiles, plus spare parts and ground support equipment. The figure includes a $20-million letter contract of last September.

Jupiter Missiles

Chrysler Corp. received an $18 million Army contract for the Jupiter missile program.

Corporal Order

The Army has awarded Firestone Tire and Rubber a $5,866,920 contract for work on the Corporal missile.

Solid Propellant Motors

A $2,383,173 development contract for an unspecified number of improved high performance XM33 solid propellant rocket motors has been awarded to Thiokol Chemical by the Army Rocket and Guided Missile Agency for NASA.

Propellant R&D

Monsanto Chemical Special Projects Dept. will conduct a research program on propellants under a Navy BuOrd contract.

X-7 Ramjet Tests

Lockheed Missile Systems Div. has been awarded a new Air Force contract, expected to exceed $8 million when finalized, to continue test flights of the recoverable X-7 ramjet vehicle.

Telemetering Systems

Applied Science Corp. of Princeton (ASCOP) has received a $500,000 subcontract from ITT Labs for three telemetering ground-station systems for Eglin AFB Gulf Test Range, Fla.

Sparrow Test Sets

Allen B. Du Mont Labs will produce 22 universal missile test sets for the Navy's Sparrow III program under a $1.3 million subcontract from Raytheon.

Blowdown Wind Tunnel

A contract for an angle-of-attack control system for a blowdown wind tunnel located at McDonnell Aircraft's St. Louis facility has been awarded to CDC Control Services, Hatboro, Pa.

New AEW Radar System

Substantial initial contracts for a new airborne early warning radar system (AN/APS-95) have been awarded to Hazeltine Corp. by the Air Materiel Command.

NASA Computer

A new high-speed computer, to be used for large-scale computations of space problems at unprecedented speeds, will be manufactured for NASA's Lewis Research Center, Cleveland, by Telemeter Magnetics.

NSF Issues R&D Contract

The National Science Foundation has awarded Itek Corp. a $143,000 contract for a basic R&D program on information searching systems that will help scientists and technologists with the rapidly-growing literature of their fields.

Polaris Test Equipment

Aircraft Armaments, Inc., Cockeysville, Md., has received a GE subcontract for development and manufacture of test equipment for the Polaris missile program.

SYNOPSIS OF AWARDS

The following synopsis of government contract awards lists formally advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army, and Navy contracting office:

AIR FORCE

AF Missile Test Center, ARDC, USAF, Patrick AFB, Fla.

Increase in funds, $163,063, **Ampex Corp.**, 934 Charter St., Redwood City, Calif.; $69,792, **Morton Schiff Co.**, 601 Virginia Dr., Orlando, Fla.; $26,930, **Nems-Clarke Co.**, Div., of Vitro Corp. of America, 919 Jesup-Blair Drive, Silver Spring, Md.; $63,163, **Photo-Sonics, Inc.**, 2704 W. Olive Ave., Burbank, Calif.

Hq, AF Cambridge Research Center, ARDC, USAF, Laurence G. Hanscom Field, Boston, Mass.

Studies on tracking of artificial earth satellites, $104,712, **Univ. of Alaska**, College, Alaska.

Design study to determine criteria for superpressure balloons, $26,627, **General Mills, Inc.**, 2003 E. Hennepin Ave., Minneapolis, Minn.

Research of solar phenomena, $43,000, **Harvard College**, Cambridge, Mass.

Study of physical, chemical, and magnetic properties of thin ferromagnetic films for use as a memory device, $69,995, **Sperry Rand Corp.**, Remington Rand Univac Div., 19 St. and West Allegheny Ave., Philadelphia, Pa.

Study of methods and procedures of mathematical circuit analysis and design adapted to machine computation, $29,-018, **Sperry Rand Corp.**, Remington Rand Univac Div., 19 St. and West Allegheny Ave., Philadelphia, Pa.

Hq, AF Office of Scientific Research, ARDC, Washington 25, D.C.

Continuation of research on microwave solar radiation, $91,000, **Stanford Univ.**, Stanford, Calif.

Continuation of research on statistical thermodynamics, $25,600, **MIT**, Cambridge 39, Mass.

Continuation of research on basic transport phenomena in germanium and indium antimonide, $55,000, **Battelle Memorial Institute**, 505 King Ave., Columbus 1, Ohio.

ARMY

Boston Ordnance District, Army Base, Boston 10, Mass.

Engineering services for Hawk missile, $5,000,000, **Raytheon Mfg. Co.**, Willow St., Waltham, Mass.

Research in measurement of re-entry bodies, $92,672, **Barnes Engineering Co., Stamford, Conn.**

U.S. Army Ordnance Dist., Los Angeles, 55 S. Grand Ave., Pasadena, Calif.

Research and development missile program, $22,000,000, **Sperry Rand Corp.**, 322 N. 21 W., Salt Lake City, Utah.

Transponders, $127,580, **Interstate Electronics Corp.**, 707 E. Vermont Ave., Anaheim, Calif.

Research and development, $947,640, **CalTech**, 1201 E. California St., Pasadena, Calif.

Design and development, $3,795,730, **North American Aviation, Inc.**, 6633 Canoga Ave., Canoga Park, Calif.

Rocket engines, $1,155,000, **North American Aviation, Inc.**, 6633 Canoga Ave., Canoga Park, Calif.

Guided missile system, $5,994,617, **Firestone Tire & Rubber Co.**, 2525 Firestone Blvd., Los Angeles 54, Calif.

Transducers, $236,396, **Topp Mfg. Co.**, 5221–5255 W. 102 St., Los Angeles 45, Calif.

Study of boundary layer surface material interactions, $34,995, **North American Aviation, Inc.**, 12214 Lakewood Blvd., Downey, Calif.

Hypersonic research, $55,000, **CalTech**, 1201 E. California St., Pasadena, Calif.

U. S. Army Ordnance Dist., Philadelphia, 128 N. Broad St., Philadelphia 2, Pa.

Fundamental study of boron chemistry adducts of high boron ratios, $40,980, **Univ. of Delaware**, Newark, Del.

U.S. Army Ordnance District, St. Louis, 4300 Goodfellow Blvd., St. Louis 20, Mo.

Design, and development, limited fabrication, and test of metal parts for rocket motor, $200,000, **Emerson Electric Mfg. Co.**, 8100 Florissant Ave., St. Louis, Mo.

NAVY

Department of the Navy Bureau of Aeronautics, Washington 25, D.C.

Installation of test facilities for the Corvus missile, $674,725, **Temco Aircraft Corp.**, Dallas, Tex.

Attitude Control

(CONTINUED FROM PAGE 35)

an attitude control system for such missions as scientific observation or military reconnaissance.

The attitude of the winged vehicle must also be controlled as it re-enters the atmosphere. In the initial stages of re-entry, it may be desirable to adjust the drag and lift of the vehicle by changing its attitude. A probable sequence would be to fly the vehicle normal to the air stream for high drag and then rotate it into a high-lift configuration as it goes into the region of high dynamic pressure, and, therefore, high aerodynamic heating.

Let us now look further into the matter of the need for attitude control for manned satellite vehicles and winged vehicles in space. The question is often asked why a vehicle in space does require an attitude control system. One answer to this question can be seen in a brief consideration of the separation of vehicle and booster. Even with the most careful engineering practices, it is virtually impossible to release a vehicle from its booster without imparting to it at least a small rotation about one or more of its principal axes.

Particularly in the case of satellite vehicles, even a very small angular velocity imparted at separation will continue unless something is done about it. Some vehicles (for example, the Pioneer moon probe) can be initially stabilized after leaving the booster by imparting a roll velocity. This method will stabilize a vehicle for a short period; but, if the body possesses any mass dissymmetry, there will be an inertial coupling which may cause the initial roll to be changed into a yaw or pitch angular velocity. It is not possible, of course, to use spin stabilization in this way for a manned vehicle or any scientific satellite which must have a fixed orientation relative to the Earth or other celestial bodies.

Since there are no aerodynamic forces acting on a vehicle in space, other forms of control must be adopted to achieve and maintain an orientation. There are two general ways of obtaining attitude control in space: (1) By changing the angular momentum of the vehicle by internal flywheels or by pumping fluids in circular tubes; and (2) by the use of reaction controls, utilizing internal gas supply or other thrust producing devices.

The figure at the top of page 34 shows an orientation control system suitable for satellite vehicles in orbit and initially oriented. The system has two gimbal-mounted flywheels, an optical system, drive motors, and a computer. Pitch and roll sensors are employed, and a rate gyro mounted on the roll axis is nulled to correct yaw attitude. The flywheel reaction system maintains a constant pitch rate consistent with the particular orbit, so that the vehicle can at all times be oriented with respect to the ground beneath it. It is necessary to consider in the flywheel reaction subsystem the possibility of angular momentum changes due to internal equipment, and to make adjustment for such changes.

In the development of attitude-control and guidance components and systems, it is necessary to ground-test operation and performance in a flight like the one shown on page 35. This simulator consists of a flight table on which the equipment to be evaluated or tested is mounted; a hydraulic power supply; and control and test consoles. The flight table and console are mated with an analog computer making it possible to simulate the flight motion of a vehicle while utilizing the actual components of a control system.

Problems of Re-entry

We turn now to the problem of re-entry. Density of an idealized isothermal atmosphere can be expressed by an exponential function, as follows: $\rho = \rho_0 e^{-h/c}$, where ρ is the density at some reference altitude (usually sea level) and c is the scale height, chosen to give the most nearly correct density in the altitude range of interest for the attitude control problem. An aerodynamically stable body, on entering such an atmosphere, will, after some time, begin to oscillate. Oscillations will be violent if the body enters the atmosphere at very large angles of attack (i.e., close to a point where $\alpha =$ 180 deg) and will be rather complex if initial spin is applied to the body. (Linear oscillations are described by M. Tobak of Ames Research Center in this issue.)

The design of the re-entry vehicle is influenced both by the amplitude and frequency of body oscillations, and it may be desirable to incorporate an attitude control system which will reduce such oscillations or damp them out completely.

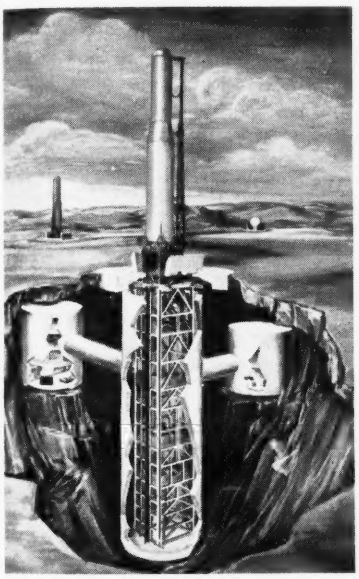
One principle of operation for such an attitude control system can be based on arranging the attitude of the re-entry vehicle so the oscillations never occur. On the other hand, it is also feasible to take advantage of the fact that an aerodynamically stable body does oscillate and that these oscillations can subsequently be controlled.

The first system requires that the vehicle "remember" some reference

attitude and that reaction jets be activated if the vehicle strays substantially away from this attitude. The second system, first developed by AVCO for possible use on an ICBM re-entry vehicle, is lighter, simpler, and more reliable. It has the great advantage of leaving the re-entry vehicle to its own devices until the attitude control system is really needed, i.e., just before the re-entry phase.

This same philosophy is applicable to certain satellite re-entries. In principle, a hypersonic winged vehicle could take advantage of such a system but, as discussed earlier, it would more likely be attitude-controlled throughout flight, and thus escape the buildup of aerodynamic oscillation.

Titans Underground

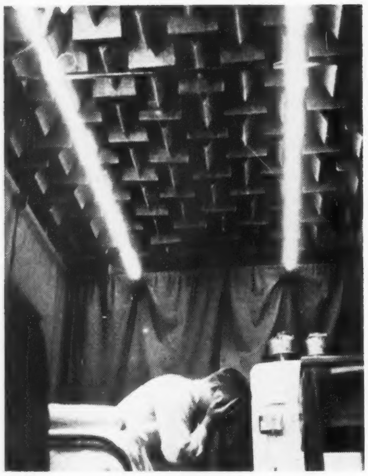


This drawing depicts Titan underground launching complex being developed by American Machine and Foundry for the Air Force at Vandenberg AFB in Calif. An elevator boosts the missile to the surface for launching; underground bunkers receive telemetry communication and direct firing.

Declassification Program Underway

A new declassification program began recently to increase the flow of scientific and technical information to industrial and educational institutions and the press. Millions of military documents originated prior to Jan. 1, 1946 will be affected.

Isolate, Silent Space



A reporter sits in the no-echo chamber at Wright-Patterson AF Base and experiences the silence and isolation of space.

Problems and Progress

(CONTINUED FROM PAGE 39)

Such considerations led them to suggest a blunt body of high form drag for the general re-entry shape when aerodynamic heating is a price consideration.

Before turning to a discussion of the interesting problems facing the aeronautical engineer once W/C_DA or the trajectory for a re-entry design has been given, it should be pointed out that many ingenious fixes have been suggested to reduce the heating problem for a given set of conditions. In general, these have not eliminated nor, in the opinion of the author, will they eliminate the heating problem. For, as soon as a fix is found, the desire to increase accuracy and decrease vulnerability increases the design velocity, with the result that the designer is still faced with a difficult heat transfer problem. If this is true, one should be able to discuss the heat transfer problems of the simplest bodies, since the questions which arise about these unfixed bodies will in general arise about any fixed body, albeit at higher velocities.

Low-High Re-entry Velocities

In discussing the heating of re-entry vehicles, there is a rather natural division that can be made to separate two orders of magnitude of the heat transfer problem. For the lower re-entry velocities or low W/C_DA, the energy absorbed by a body is of an order that can be handled by using the ordinary heat capacity of a good conducting solid as a heat sink. For the higher re-entry velocities or high W/C_DA, this simple method is insufficient and one must turn to the use of the latent or chemical heat of some physical or chemical change as a means of absorbing re-entry heat. Both methods have some common features, but in the discussion below the two types and the research associated with each are discussed separately.

It is obvious that the heating problem will be of a lesser magnitude if the boundary layer on the vehicle is laminar. Early work on boundary layer stability indicated that the effect of favorable pressure gradient and low surface temperature should be beneficial on transition.

However, recent work by the NASA Lewis Research Center has shown that the effect of body shape, pressure gradient, surface temperature, and surface roughness are not so well understood. These experiments have led to a complete re-evaluation of the status of our knowledge of boundary layer stability and to an intense theoretical and experimental effort to further our basic knowledge of the factors affecting boundary layer transition.

In addition to the problem of determining boundary layer transition, the designer of an ordinary heat-sink vehicle runs into a number of other interesting phenomena which as yet are not too well understood. This is particularly true at the highest values of re-entry velocity and W/C_DA which are possible for this type of design. There is the problem of the effect of extreme boundary layer temperature gradients on the nature of the turbulent boundary layer. There is the problem of how much ionization and dissociation of the air in the immediate vicinity of the missile will occur, and how great an effect this will have on the flow both external to and inside the boundary layer on the body. Then there is the problem of how much heat is transferred by radiation, as well as a host of other questions, all of a very basic nature, that nonetheless probe the limits of our present knowledge of physical phenomena.

All these questions are equally applicable to the design of a re-entry vehicle at higher velocities and higher W/C_DA, only more so. In addition, when some surface fluid injection or mass ablation is used to prevent destruction of the missile, there is the added complication of determining boundary layer characteristics under such conditions.

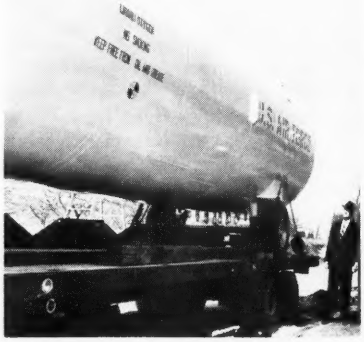
In the first method mentioned above, the surface remains fixed while a protecting layer of coolant is spread over it. This may be accomplished by introducing the coolant at the very front of the vehicle, in which case it is swept downstream over the entire body, or by distributed addition along the entire surface. The coolant may be a liquid which evaporates or a gas which does not, depending on the particular trajectory.

In the second method, the surface of the body is allowed to reach a temperature where it undergoes an endothermic reaction, thus taking care of the heat transferred to the body. For this type of protection, a portion of the vehicle surface ablates during re-entry. Recently, significant advances in the theory of chemically reactive boundary layers have been made, but the problem has by no means been solved. Experimental techniques are being brought forward to reproduce in the laboratory the conditions of heat transfer encountered in flight. By such means, the effectiveness of various surface materials can be compared and experimental data gathered so as to guide the more advanced theoretical attacks on the problem.

Unfortunately, space and security restrictions do not permit a more extended discussion of re-entry. However, it should be plain from this brief outline of the problem that there is no lack of unsolved problems, both theoretical and experimental, in this particular field of engineering. It is hoped that this paper, though of necessity quite short, will demonstrate the very great scope of our physical knowledge which must be called upon before the problem is solved.

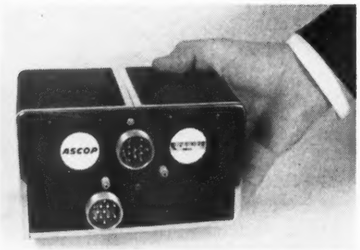
Surely the design of a re-entry vehicle is one of the most fascinating engineering challenges of the day.

Giant Lox Tank



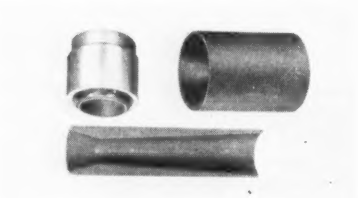
Said to be world's largest air portable tank, this big baby will store lox for fueling the AF Thor at Camp Cook, Calif. It consists of aluminum outer and stainless steel inner tanks, respectively, made by Cambridge Corp., Lowell, Mass.

New equipment and processes

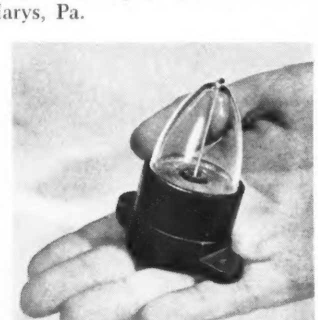


Oscillographic Recorder: The size of a box camera, this recorder, available in several versions, can handle six analog-data channels and three on-off channels for event marks. A typical model weighing 3.5 lb provides continuous running time from 1 min. to 50 hr. Applied Science Corp. of Princeton, P.O. Box 44, Princeton, N.J.

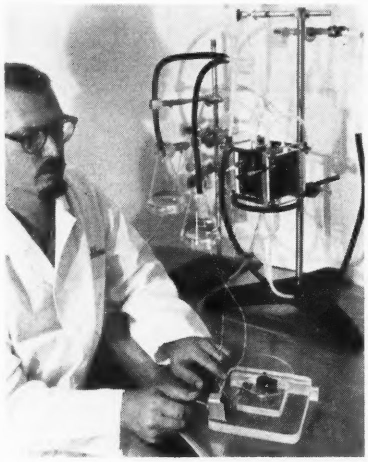
Broad-Band Preamplifiers: Available in a series covering the range 50 to 500 mc. A typical unit accepts everything from 50 to 300 mc with noise level between 5 and 8 db and dynamic range 60 db or better. The Singer Mfg. Co., Military Products Div., 149 Bdwy., New York 6, N.Y.



Rocket Exhaust Nozzles: Special forms of graphite molded and machine in nozzle form withstand the thermal shock and high temperature of rocket exhausts without melting, fusing, or distortion. The graphite inserts can be machined to the close tolerances required for a tapered throat. Stackpole Carbon Co., St. Marys, Pa.



Impact Switch: This switch operates in 90 to 200 microsec between −80 and 185 F. It can be made of 95 per cent nonmetallic materials for installation near radar. Servonics Engineering Services Co., 4645 Van Nuys Blvd., Sherman Oaks, Calif.

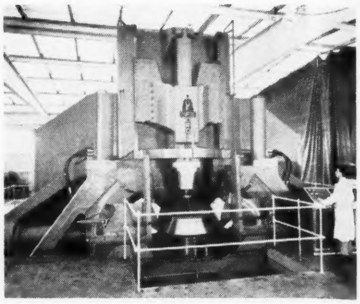


Electrochemical Conversion: Lockheed Missile Systems Div. is developing a "fuel" cell for electrochemical conversion that already has given conversion efficiency of over 70 per cent and almost 100 per cent "fuel" utilization. Besides running common electric motors, the cell might find important use providing power for communications systems and other internal equipment in spacecraft requiring a long-lasting power supply, and for operation of scanning and recording equipment in scientific space projects, such as lunar probes. Lockheed Missile Systems Div., Sunnyvale, Calif.

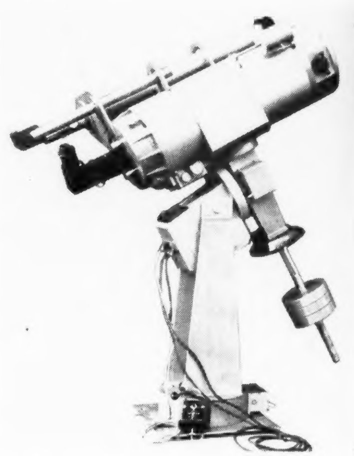
Foamed Metal: GE is developing a metal (F-alloy) that resembles petrified sponge and is nine-times lighter than solid metal. Metal of this kind is a step toward lighter, more efficient engines for recoverable air-breathing boost units, VTO systems, and hypersonic vehicles. Nickel, copper, and cast iron have been successfully foamed. GE Flight Propulsion Laboratory Dept., Aircraft Gas Turbine Div., Cincinnati, Ohio.

Thermoelectric Generators: 3M models based on heated semiconductors give an operating efficiency of about 6 per cent. One generator is an air-cooled 5-w unit for use with an isotope heat source. Similar units are being designed for cooling by water and radiation. Related devices would also be capable of cooling or heating. Minnesota Mining and Mfg. Co., St. Paul, Minn.

Metal Forming Machine: This "Spin Forge," weighing almost 250 tons, can

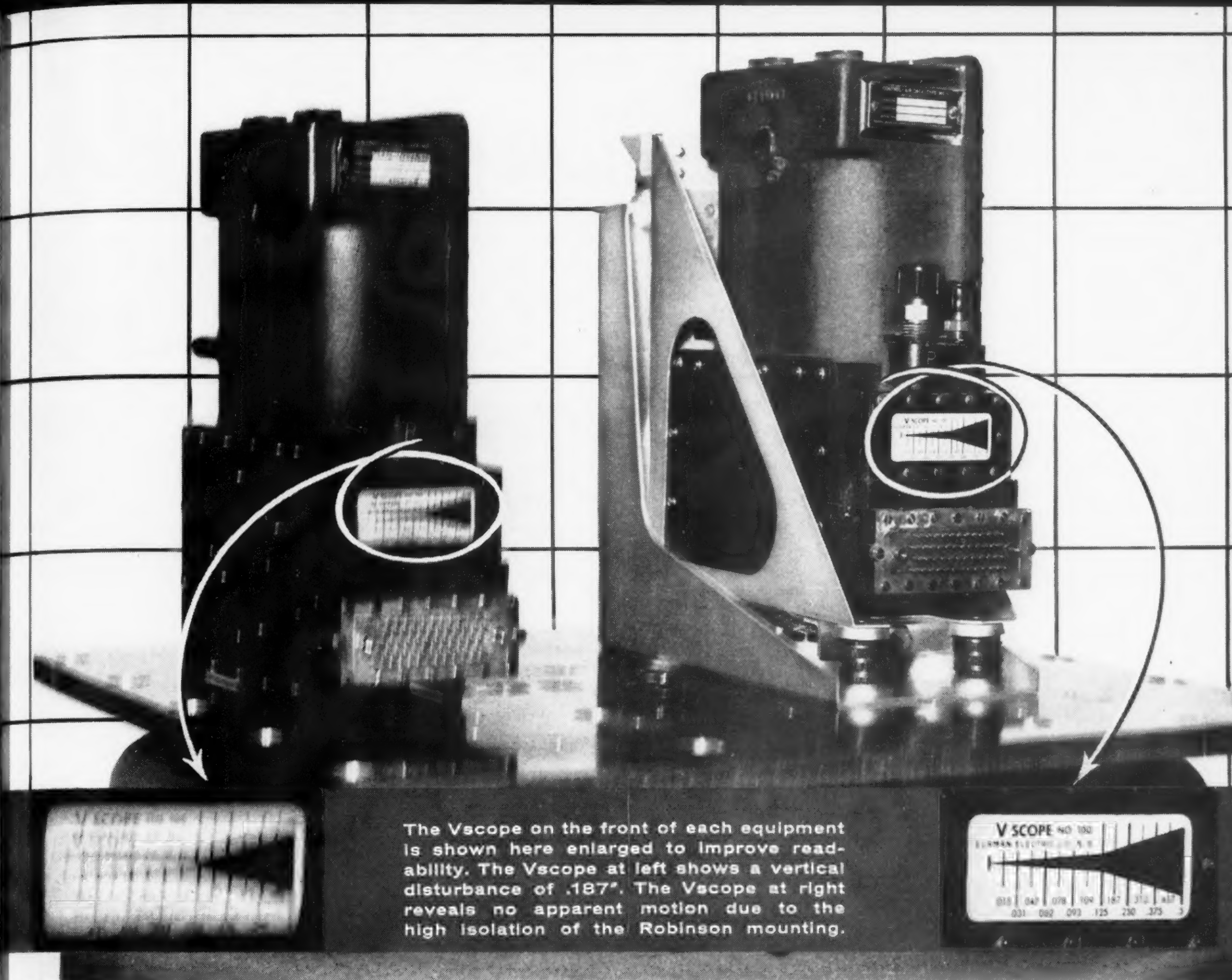


apply a total work force greater than 1 million lb to form parts up to 60 in. in diam and 10 ft high. It cuts the production cycle for producing certain rocket engine cases by more than 50 per cent and improves the finished quality of the metal. The unit combines rolling and shearing to produce conical, tubular, or parabolic shapes with varied wall thickness. Hufford Corp., Div. of The Siegler Corp., El Segundo, Calif.



Satellite Tracking Telescope: A Newtonian-Cassagrainian reflecting telescope designed and manufactured by Tinsley Labs is being installed in the Ames Observatory in Texas. It has a 12-in. aperture, weighs over 1000 lb, and incorporates 7 motors, which drive it at star- or satellite-tracking speeds. Tinsley Laboratories, Berkeley, Calif.

Klystron Transmitter: Packed in three cabinets, the Model 215T transmitter—a research unit for radar, communications, and propagation work, with connections for monitoring input and output r-f—can produce 50 kw of peak power at a maximum duty cycle of 0.06, and operates over the band 700 to 900 mc. Leventhal Electronic Products, Inc., Stanford Industrial Park, Palo Alto, Calif.



12.0 "G" reduced to 0.6 "G"

This Is Environmental Protection!

Look at the above illustration, showing two Bendix air data sensors on an electromagnetic shake table. Notice the left hand unit which is mounted solidly to the oscillating head of the shaker. The image is blurred because a vibratory input of about .187" double amplitude at 35 c.p.s., equalling an acceleration force of 12 "g's", is being applied directly to it.

Now look at the right hand unit mounted on a Robinson engineered mounting system . . . some difference! The clear image of this equipment shows the typically high isolation efficiency (over 95%) of the Robinson MET-L-FLEX® mounting design.

Other Robinson designs provide similar protection at higher frequencies where the input often reaches 30-40 "g's". The natural frequencies of such mounting systems are held within limits which are not critical to the equipment.

Utilizing this mounting system radically reduces the environment to a level easily tolerated by any reasonably well designed electronic equipment. Such a mounting eliminates the need for costly and time consuming ruggedization. Over-all space and weight are held to a minimum.

Because of the proven performance and reliability record of airborne components *now* protected by Robinson mountings, an increasing number of manufacturers in the electronics industry are incorporating Robinson mountings as an *integral part* of their basic equipment design.

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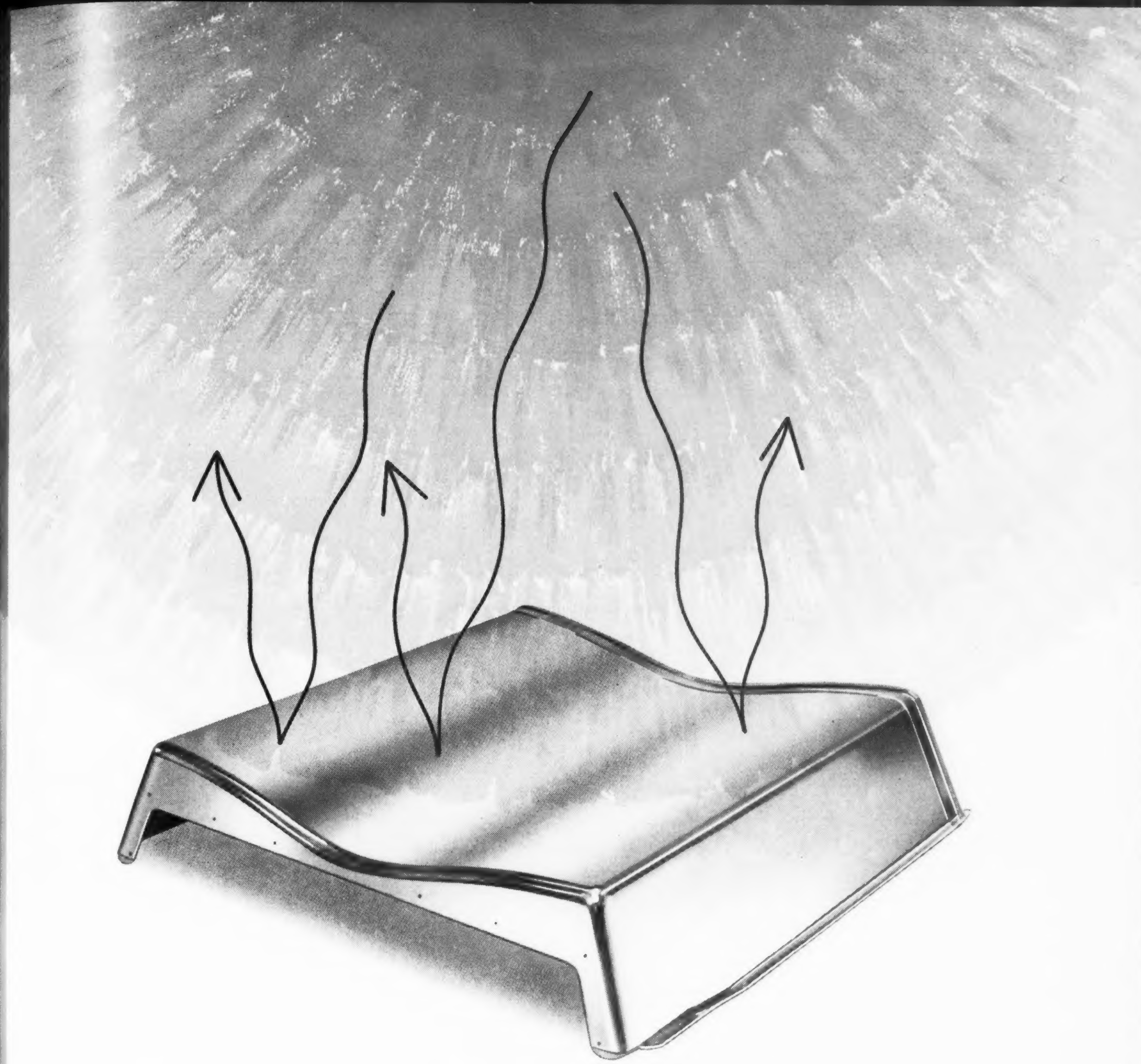
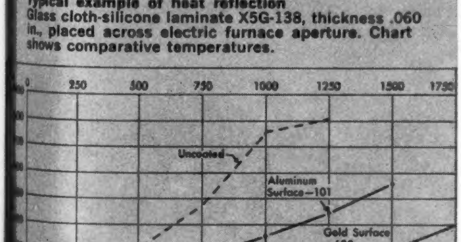


Now, reflect up to 1750°F radiant heat from SWEDLOW metallized laminates

Typical example of heat reflection
Glass cloth-silicone laminate X5G-138, thickness .060 in., placed across electric furnace aperture. Chart shows comparative temperatures.



Furnace Temperature —°F.

Compound shapes—minimum weight and bulk—highly efficient reflectivity—distinguish these materials and solve the problem of resistance to elevated temperatures.

Swedlow's solution for light weight heat protection problems uses a base of fiberglass fillers. To these are added any of an impressive variety of silicone, phenolic, epoxy, TAC polyester or polyester binders to meet specific service conditions. The resulting high-strength laminate is furnished flat or molded to any contour desired. Metallic coatings then further increase heat reflectivity and resistance. Swedlow-pioneered Type -101 aluminum coating is now in wide use for the 200°F to 1400°F range. The more recently developed Type -603 gold now raises the limit to approximately 1750°F.

Swedlow research is continuing the development of many combinations for the growing variety of aircraft, missile and electronic applications. To learn how these new materials can help solve your heat problems, contact the Swedlow plant nearest you. Or send for new literature—"Radiant Heat Reflective Laminates." Please refer to Dept.

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